USAARL Report No. 2016-05

Analysis of Nonlinear Insertion Loss of Hearing Protection Devices using an Acoustic Test Fixture

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September 2015

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REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 0704-0188*
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1. REPORT DATE *(DD-MM-YYYY)* 30-11-2015	**2. REPORT TYPE** Final		**3. DATES COVERED** *(From - To)*
4. TITLE AND SUBTITLE Analysis of Nonlinear Insertion Loss of Hearing Protection Devices using an Acoustic Test Fixture		**5a. CONTRACT NUMBER**	
		5b. GRANT NUMBER	
		5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Williams, Robert Reeves, Efrem Chen, Michael		**5d. PROJECT NUMBER**	
		5e. TASK NUMBER	
		5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Aeromedical Research Laboratory P.O. Box 620577 Fort Rucker, AL 36362			**8. PERFORMING ORGANIZATION REPORT NUMBER** USAARL 2016-05
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S Army Medical Research and Materiel Command 504 Scott Street Fort Detrick, MD 21702			**10. SPONSOR/MONITOR'S ACRONYM(S)** USAMRMC
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			
13. SUPPLEMENTARY NOTES			
14. ABSTRACT The report details insertion loss measurements from multiple types of hearing protection devices in order to examine the nonlinearity of insertion loss. Tests were conducted in continuous noise from 55 to 130 decibels (dB) and impulsive noise from 110 to 170 dB peak sound pressure levels. Results show that predictive models for the protective capacity of hearing protection should account for variability in insertion loss, depending on the incident sound pressure level.			
15. SUBJECT TERMS hearing protection, impulse noise, insertion loss, acoustic test fixture			

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Loraine St. Onge, PhD
UNCLAS	UNCLAS	UNCLAS	SAR	231	**19b. TELEPHONE NUMBER** *(Include area code)* 334-255-6906

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Introduction

Hazardous noise exposure is incredibly common in modern society. Many individuals are exposed to some sort of noise daily whether working or participating in leisure activities. Noise induced hearing loss, however, is not inevitable; rather, it is almost entirely preventable if appropriate hearing conservation measures are taken.

The best way to prevent noise induced hearing loss is to reduce the sound pressure level (SPL) of noise sources so that exposures are below damaging levels. In practice, however, it is far more common to limit time in which personnel may be exposed to noise and require that hearing protection devices (HPDs) be worn when personnel are exposed to noise (Suter, 2010). In order to prescribe appropriate HPDs, it is necessary to understand the protective capacity of the HPD. Various metrics and measures are used to describe the protective capacity of HPDs, though most metrics are described as a reduction in effective exposure (Nixon and Berger, 1998).

One such metric is the noise reduction rating (NRR). The NRR is a one number approximation based on a weighted average of the frequency-dependent real ear attenuation at threshold (REAT) test results. The NRR is subtracted from the A-weighted exposure SPL (the actual exposure), resulting in an assumed SPL (the effective exposure) (Nixon and Berger, 1998). For example, if personnel working in an environment with 90 decibels A-weighted (dBA) SPL noise wear HPDs with an NRR of 30 dB, their assumed effective exposure would be 60 dBA. Noise reduction rating is assumed to be constant. In other words, the NRR does not change based on the SPL of the actual exposure.

Other methods for estimating protective capacity, such as the model from Kalb (2013), also use constant protective capacity assumptions. The Kalb model uses interpolated REAT data to create a frequency dependent magnitude response for the HPD. A three-path lumped parameter model is fit to the frequency response and used to predict the time domain waveform under the protector based on a time domain waveform recorded in the sound field of a noise source (2013).

An assumed constant protective capacity for HPDs may not be sufficient for newer types of HPDs. Devices classed as passive nonlinear protectors feature a very small diameter vent between the atmosphere outside the protector and the volume of air trapped under the protector. Such protectors are marketed as blocking high-intensity sounds while passing low-intensity sounds. The intent of such devices is to protect the wearer from impulsive noise (such as gunfire) while still allowing a certain amount of auditory situational awareness and speech communication.

Other types of HPDs are available with active nonlinear features, also called talk-through circuitry. Talk through circuits use electro-acoustic transducers to pass ambient sounds through the protector. When the circuitry detects sound levels outside the protector above a certain threshold, the circuitry either compresses the signal (provides an attenuated signal through the electronic path) or shuts off entirely to protect the wearer from high-level noise. These devices may also provide amplification to allow the user to better detect quiet sounds.

The active and passive nonlinear protectors are marketed as providing variable protective capacity based on the SPL of the acoustic insult. If the protective capacity is variable, it should be accounted for in the selection of appropriate HPDs. REAT measurements are not conducted at a set SPL, but are rather performed at the audiometric threshold of the test subject (between 0 and 60 dB, depending on the frequency band and the individual) (ANSI, 2008). Real ear attenuation above threshold testing is conceivable, but would require exposing participants to hazardous noise levels if testing were conducted at levels equivalent to the exposure that the protector is designed to attenuate. Supra-threshold testing of HPDs is accomplished using microphone in real ear (MIRE) or acoustic test fixture (ATF) methods.

Microphone in real ear and ATF measurements are very similar in that both measure the insertion loss provided by the protector. Insertion loss is the difference in SPL measured using a microphone at a given location with and without the protector in place. The noise level, spectral content, duration, etc. may be carefully controlled depending on the test conditions. For MIRE measurements, the microphone is located near the entrance of the ear canal of a human participant, usually attached to some sort of insert earplug. For ATF measurements, the microphone is located inside a simulated ear installed in a head form that takes the place of the human participant (ANSI, 2010). Insertion loss is typically not used to calculate protective capacity because it does not account for all of the flanking paths (tissue conduction, etc.) that sound may use to reach the cochlea. It is useful, however, in describing the behavior of sound transmission through the protector or certain flanking paths (leaks around seals, etc.).

The American National Standards Institute (ANSI) published a standard in 2010 (ANSI S12.42-2010) detailing methods for measuring the insertion loss of a hearing protector using an acoustic test fixture. Included in the standard is the definition of the impulsive peak insertion loss (IPIL), which is the difference in peak sound pressure given an impulsive noise. The ANSI standard specifies waveforms with positive phase durations (also called A-durations) between 0.5 and 2 milliseconds (ms), with peak pressures at three different levels (approximately 130, 150, and 170 dB peak) (ANSI, 2010).

Test results using this standard sometimes indicate an increase in peak insertion loss with increasing peak SPL (regardless of the supposed linearity or nonlinearity of the device), which leads to an interpretation of increasing protective capacity of the device (Murphy, et al. 2011; Department of the Army, 2013). This interpretation makes a number of assumptions that are not necessarily valid. The ANSI standard allows a wide range of A-duration values, which in turn allows a wide range of frequency content in the signal used to calculate the insertion loss. It is possible that two different tests of the same protector using different impulse noise sources will provide different results simply because the peak metric ignores the frequency content of the input signal. As a result, it is worth questioning if the apparent passive nonlinearity is the result of differing frequency content in the input signal, meaning the frequency dependent insertion loss could be constant with respect to the SPL of the input signal. At the same time, the potential for protective capacity that varies depending on the noise exposure is not something to be dismissed, especially with protectors that feature intentionally nonlinear design elements.

To help improve the understanding of the performance of HPDs, this report details measurement of the insertion loss of several different hearing protectors in a wide range of

continuous and impulsive SPLs. The insertion loss is calculated in third octave bands to demonstrate if nonlinearity is present in devices without nonlinear elements. Methods for interpreting nonlinearity are suggested, along with suggestions for future studies.

Study objectives

The purpose of this study was to examine nonlinearity in the insertion loss of hearing protection devices. In order to do so, the insertion loss of several different types of hearing protection devices was measured across a wide range of SPLs, using both impulsive and continuous noise sources. The resulting data were analyzed to determine the third octave band insertion loss, which is examined for variation as a function of the third octave band SPL. Implications to the protective capacity of HPDs are discussed.

Methods

Devices tested

Several devices were examined during the course of this study. These devices were selected based on the authors' best efforts to examine typical or common types of hearing protectors, rather than examining specific devices based on widespread use or desirability to end users. The devices are referred to by their trade names for the sake of clarity. The devices tested were the EAR Classic™, the Combat Arms Earplug™ (double-ended type), the Etymotic EB15, the TEA Invisio®, and the TEA Invisio® push to talk (PTT) module with an MSA Sordin headset (hereafter referred to as simply as the MSA Sordin).

The EAR Classic™ is an expandable foam earplug without nonlinear elements. The plugs are cylindrical in shape, yellow in color, and available in one size. This device was chosen to be representative of an expanding foam earplug.

Figure 1. EAR Classic™ earplug (3M).

The double-ended type Combat Arms Earplug™ is essentially two hearing protectors in one device. The green end of the plug is a preformed, triple-flanged earplug (and was chosen to represent the same), while the yellow end is a preformed, triple-flanged, vented earplug (and was likewise chosen to represent a preformed vented plug). The vented plug is used to represent a passive protector with nonlinear elements. The double-ended Combat Arms Earplug™ is available in one size.

Figure 2. Combat Arms Earplug™ (3M).

The Etymotic EB15 is an electronic hearing protection device with a nonlinear talk-through circuit. In essence, this means that the plug has an external microphone (exposed to external noises) and an internal speaker (that produces sound in the ear canal). External noises are captured by the microphone and transmitted through the talk-through circuit to the internal speaker. These sounds may be amplified, nominally unchanged, attenuated, or not transmitted depending on the operation of the talk-through circuit and user set gain states. The EB15 has two gain states (high and low) and also functions as a passive plug when unpowered. Several types and sizes of ear tips may be used with the EB15; for this study only the small, preformed, triple-flanged tip was used.

Figure 3. Etymotic EB-15 BlastPLG™ and ear tips (Etymotic).

The TEA Invisio® is an electronic hearing protection device that is similar in operation to the Etymotic EB15. The Invisio®, however, has an external PTT module that provides power to the device and allows it to interface with tactical radios and communication systems (radio communication functions were not tested as part of this study). It also has eight different gain settings and functions as a passive plug when unpowered. The earplug portion of the TEA Invisio® uses a Comply expandable foam ear tip, and has a molded plastic retention system that fits in the pinna. The standard size Comply tip was used for this study.

Figure 4. TEA Invisio® (TEA).

The TEA Invisio® PTT may also interface with the MSA Sordin headset. The MSA Sordin headset is a circumaural headset with gel-filled ear cup seals and a flexible boom microphone. It functions in the same manner as the TEA Invisio®, with the addition of the boom microphone signals being retransmitted into the ear cup (also called sideband). When attached to the TEA PTT module, it has eight gain settings and functions as a passive earmuff when unpowered.

Figure 5. MSA Sordin headset (MSA).

Five samples of the EAR Classic™ and Combat Arms Earplug™ were tested in each test condition, along with three samples of the EB15, one sample of the TEA Invisio®, and one sample of the MSA Sordin. The lower number of samples of the EB15, TEA Invisio®, and MSA Sordin were chosen because research personnel did not have additional samples of these devices.

Data collection

Impulse noise

Measurement procedures for the impulse noise insertion loss were similar to those given in ANSI S12.42-2010. An ATF was exposed to impulse noises at given peak SPLs. Pressure measurements were made by the ATF and a free field probe microphone. For this series of tests, impulses were generated at levels from 110 to 170 dB peak (as measured by the free field probe) in increments of 5 dB.

The levels from 110 to 150 dB peak were generated using a 4-in., portable, cold-gas shock tube. The shock tube was located in the United States Army Aeromedical Research Laboratory (USAARL) reverberant chamber and fired through the transmissibility pass-through into the USAARL anechoic chamber. The ATF and free-field probe were located at constant radial distances from the end of the shock tube. The desired levels were achieved by varying the pressure in the shock tube driver and changing the distance between the test fixture and the shock tube. The expansion horn was not used on the 4-in. tube, resulting in lower peak-level impulses with very short A-durations (less than 0.5 ms). Due to the variability in impulses at lower peak levels, data points were accepted as being at the nominal level if they were within 2 dB above or below the desired peak as measured using the free-field probe.

The levels from 155 to 170 dB peak were generated using the 6-in., stationary, cold-gas shock tube located in the USAARL acoustics annex. The test fixture and the free-field probe were located at constant radial distances from the end of the shock tube. Again, the desired levels were achieved by varying the driver pressure and distance between the test fixture and the shock tube. The 6-in. tube was fitted with a catenoidal expansion horn that resulted in longer A-durations (above 0.5 ms, but less than 2 ms).

The ATF used for all the impulse noise measurements was a GRAS sound and vibration 45CB head form, while the free-field probe was a GRAS 67SB free-field probe microphone. At peak levels below 155 dB peak, the head form was fitted with couplers containing ½-in. microphones; at 155 dB peak and above, couplers using ¼-in. microphones were used. All of the recordings were made using a National Instruments PXI-6123 data acquisition card with a sample rate of 500,000 samples per second. Signal conditioning for the head form and free-field probe was provided by a B&K Nexus amplifier. The input channels were filtered with six pole Bessel type low pass filters with 3 dB down frequencies of 40,000 Hertz (Hz). Additionally, the head form channels were filtered using high-pass filters with 3 dB down frequencies at 20 Hz to eliminate very low frequency distortion.

At least six un-protected impulses were recorded at the specified peak level. The unprotected shots were used to calculate the transfer function from the free-field probe to each ear of the head

form. Samples of the hearing protector under test were fit onto the head form, which was exposed to additional impulses at the same specified level. Each HPD sample was fit to the head form twice for each of the test levels and two impulses were recorded for each fitting. Each of the recordings was 1 second (s) in duration, with approximately 100 ms recorded before the peak of the free-field impulse by using an analog rising trigger to start the recordings.

All of the samples, fittings, and types of the protector were tested at the same nominal level before moving onto the next nominal level. The EB15 plugs were fit to the head form with a dead battery and tested passively, then refit to the head form with live batteries and tested at each of the active gain settings without refitting. The TEA Invisio® and MSA Sordin were tested passively and at each of the gain settings without refitting the protector to the head form.

Continuous noise

Measurement procedures for the continuous noise measurements were similar to those outlined in ANSI S12.42-2010. Sound levels for this series of tests were generated at nominal levels from 55 to 130 dB SPL in increments of 5 dB. Pink noise was used as the signal for all testing. The noise signals were verified at the test location in the test chamber at the desired SPLs using a 1-in. B&K pressure field microphone. The head form was placed in the chamber with the center of the head form located at the test point. The head form was then exposed to signals generated using the same settings as the verified levels. One set of unprotected recordings was made each day during testing. One set of protected recordings was made per sample, per fitting. A ½-in. pressure field microphone was located at a constant point near the head form for all the protected and unprotected measurements. For all of the recordings (protected and unprotected), a quiet recording was made just prior to each noise recording. The quiet recordings were made with all of the noise generation, head form microphone gain, HPD gain, etc. settings set as they were for the noise recording, but with the noise signal turned off. The quiet recordings were used to estimate the noise floor of the data acquisition systems for each of the noise recordings. Quiet recordings were made for each noise recording to account for variability in system noise and microphone gains as the testing progressed.

All of the data were recorded using a National Instruments PXIe-4462 data acquisition card and the VIAcoustics Trident software package. Data were recorded at a rate of 102,400 samples per second. Twenty seconds of data were recorded for each condition. Signal conditioning for the microphones was provided by GRAS sound and vibration 12AQ microphone power supplies. The noise signals were generated using Tucker Davis Technologies (TDT) RP2.1 devices. Those signals were output through TDT PA5 programmable attenuators into QSC PLX3602 amplifiers (running in a bridged configuration) through JBL STX825 loudspeakers located in the test chamber. Seven speakers and amplifiers were used to produce noise levels up to 130 dB.

During the continuous noise tests, each HPD sample was fit to the head form twice for each of the test levels. For each of the tests, all of the levels were recorded for the first fitting, the device was refit, and all of the levels were recorded for the second fitting. The EB15 plugs were fit to the head form with a dead battery and tested passively, then refit to the head form with live batteries and tested at each of the active gain settings without refitting. This process was done because the EB15 cannot be turned off with a battery installed and test personnel had difficulty

changing the battery without refitting the plug into the head. The TEA Invisio® and MSA Sordin were tested passively and at each of the gain settings without refitting the protector to the head form.

Data analysis

Impulse noise

The first 50 ms of each impulse noise file were isolated to estimate the instrumentation noise of the data acquisition equipment. Next, each of the recordings was time windowed from 10 ms prior to the peak (as measured by the free-field probe), until 300 ms after the peak. Research personnel noticed that some of the recordings contained artifacts that resulted from poor electrical connections or from bulk fluid flow from the shock tubes interacting with the measurement transducers. Each of the pressure versus time waveforms was plotted and visually inspected for such artifacts within the 310 ms window of data. Any files containing artifacts were discarded.

The unprotected calibration shots were used to create transfer functions from the field microphone to each ear of the ATF. The transfer functions were calculated by spectrally averaging the fast Fourier Transform (FFT) of each unprotected ear signal divided by the FFT of the free-field probe. For the protected shots, an unprotected signal was estimated by finding the inverse FFT of the product of the FFT of the free-field signal and the transfer function. This process results in three signals for each test: the protected signal (recorded by the ATF under the protector), the unprotected signal (estimated using the transfer functions and the free-field signal), and the field signal (recorded by the free-field probe).

In order to ensure that only good data were considered, the instrumentation noise of each of the signals was estimated for each measurement. For the field and protected signals, the noise floor was estimated as the first 50 ms of data that were isolated prior to time windowing. For the unprotected signals, the instrumentation noise signal was estimated as the aggregate of the first 50 ms of the unprotected recordings used to calculate the transfer functions. This resulted in an estimated instrumentation noise signal for each of the data signals (protected, unprotected, and field).

Next, third-octave band (with center frequencies from 19 to 19,952 Hz) SPLs were calculated for each of the protected, unprotected, and field signals for each recording. The third-octave band insertion losses were calculated for each data point by subtracting the third-octave band unprotected signal from the third-octave band protected signal. The signal to noise ratio for each measurement was also calculated by subtracting the third-octave band SPL of the relevant instrumentation noise signal from the measured SPLs. Any data point with an estimated signal to noise ratio in the protected, unprotected, or field signal less than 10 dB was discarded.

Continuous noise

The continuous noise analysis was conducted much the same as the impulse noise analysis; transfer functions were calculated using the field signal from the ½-in. microphone to each ear.

These functions were used to estimate the unprotected signal from each protected measurement. The instrumentation noise signals were estimated using the quiet recordings that were made during the unprotected and protected recordings.

All 20 s of data were averaged together when calculating the third-octave band levels. Again, data without at least a 10 dB estimated signal to noise ratio were rejected. The third-octave band insertion loss values were calculated in the same manner as the impulsive noise tests.

Results

Third-octave band insertion loss

Selected third-octave band insertion loss (abbreviated 1/3rd OB IL) values are plotted in Figures 6 through 41. In all of the plots, values resulting from continuous noise measurements are indicated with circles, while crosses are used to indicate values resulting from impulsive noise measurements. Right and left ear are also indicated by red and blue marks, respectively. Third-octave band insertion loss values were calculated for 31 bands with center frequencies from 19 Hz to 19 kHz. For the sake of keeping the body of the report readable, only the 251, 1000, and 7943 Hz bands are plotted in the body of the report. Data from all of the bands are plotted in the appendix.

In all of the figures, the insertion loss values are plotted as a function of the third-octave band level measured by the field transducer during the measurement. The level used for each figure is from the same third-octave band as the insertion loss (in other words, the 251 Hz third-octave band insertion loss is plotted as a function of the 251 Hz third-octave band field level).

All of the gain settings for the TEA Invisio® and MSA Sordin were tested, but data is only presented for the highest and lowest gain levels both in the body of the report and the appendix.

Passive linear protectors

Figures 6 through 20 show the third-octave band insertion loss values for the passive protectors that do not feature nonlinear design elements (the solid Combat Arms Earplug™, the EAR Classic™ earplug, the passive EB15 earplug, the passive TEA Invisio® earplug, and the passive MSA Sordin headset).

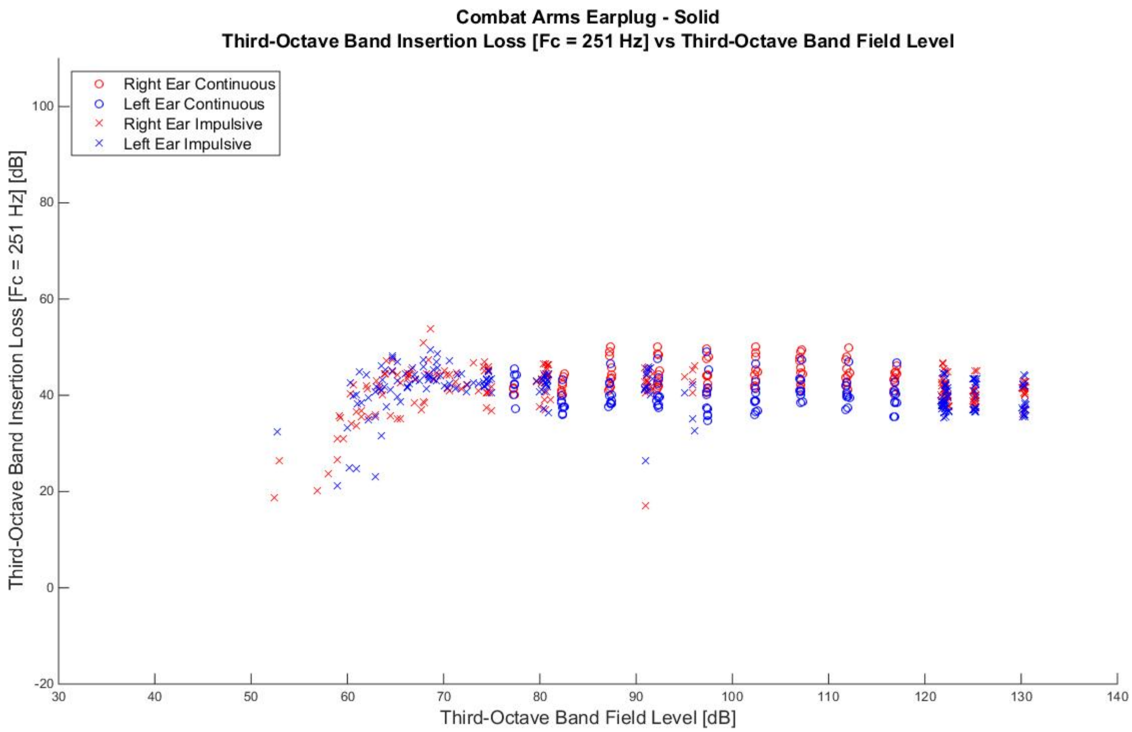

Figure 6. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

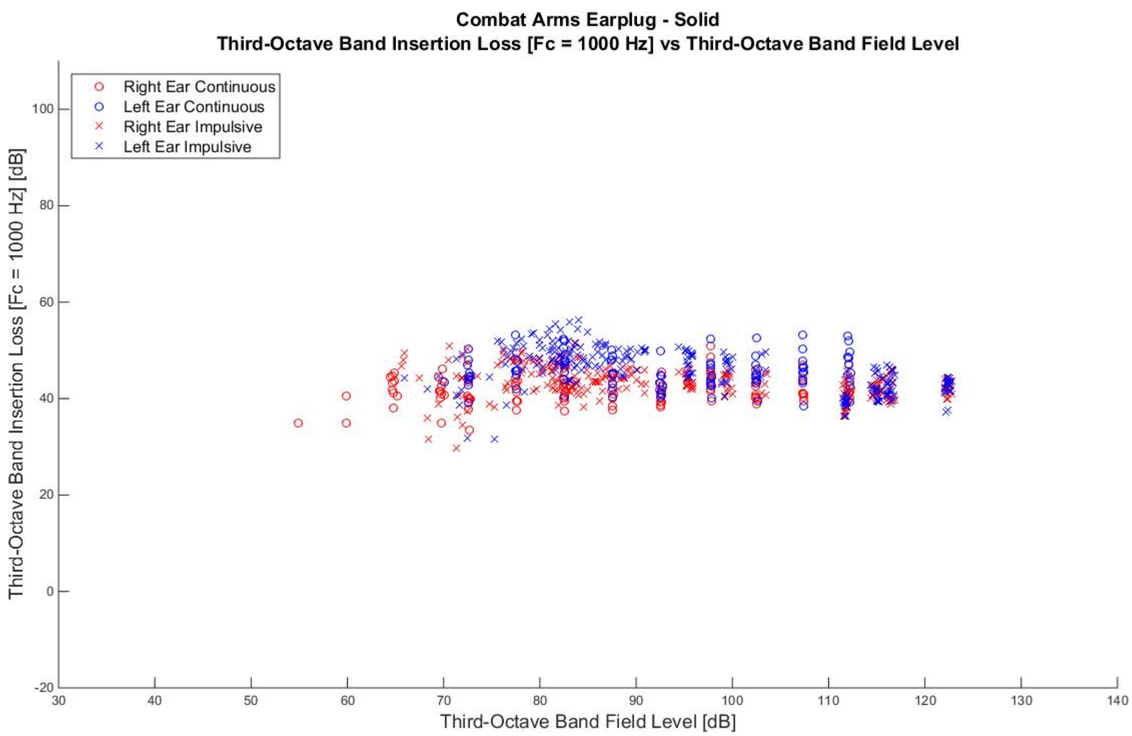

Figure 7. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

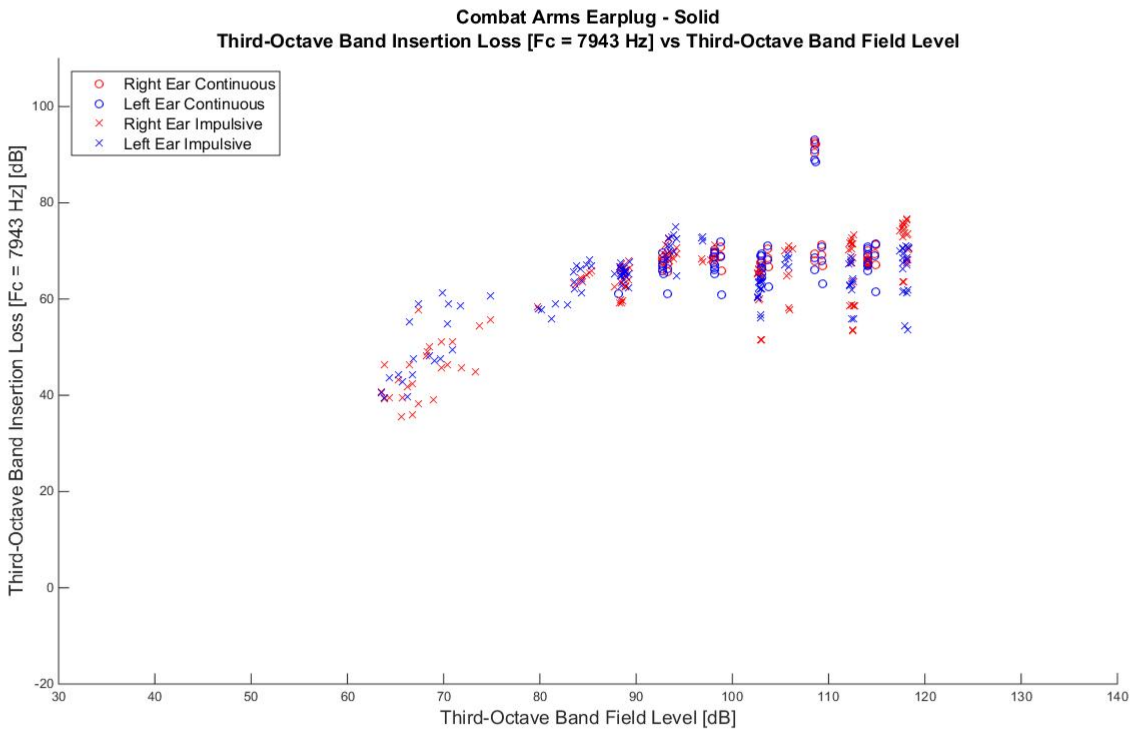

Figure 8. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

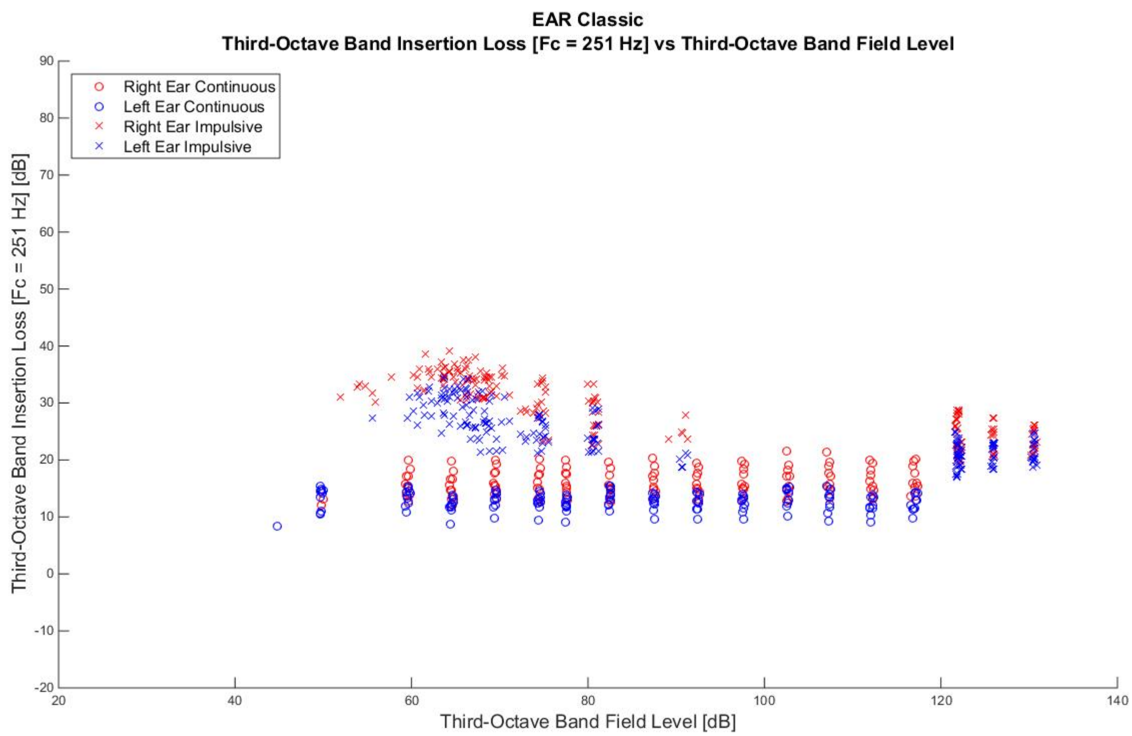

Figure 9. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

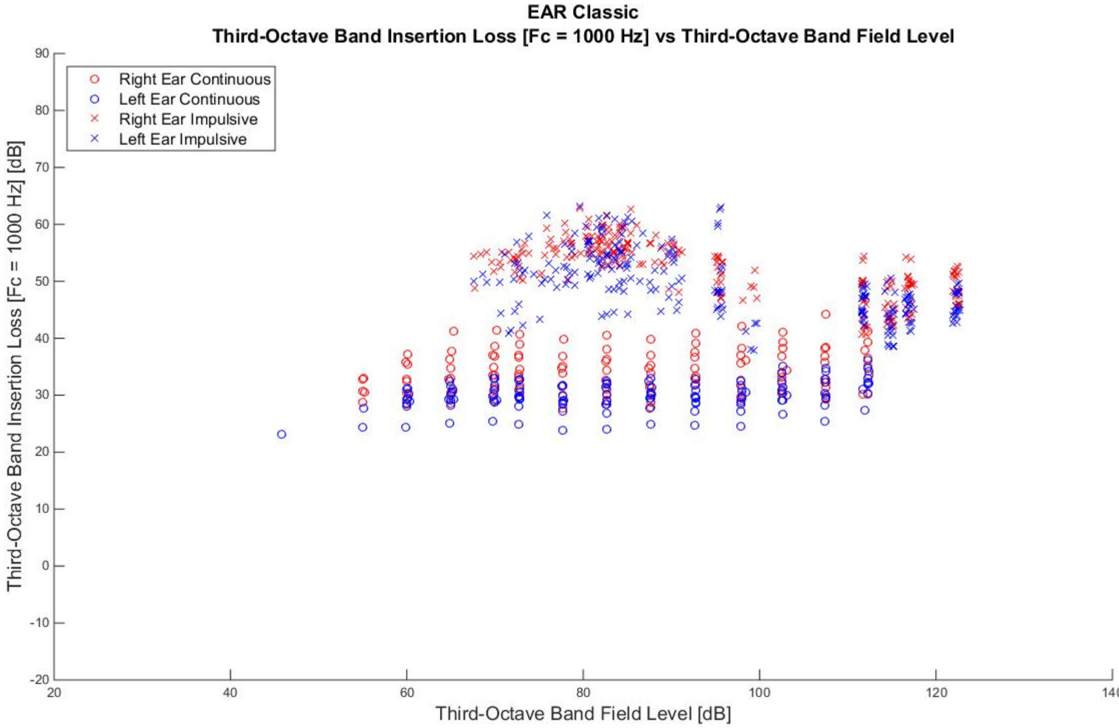

Figure 10. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

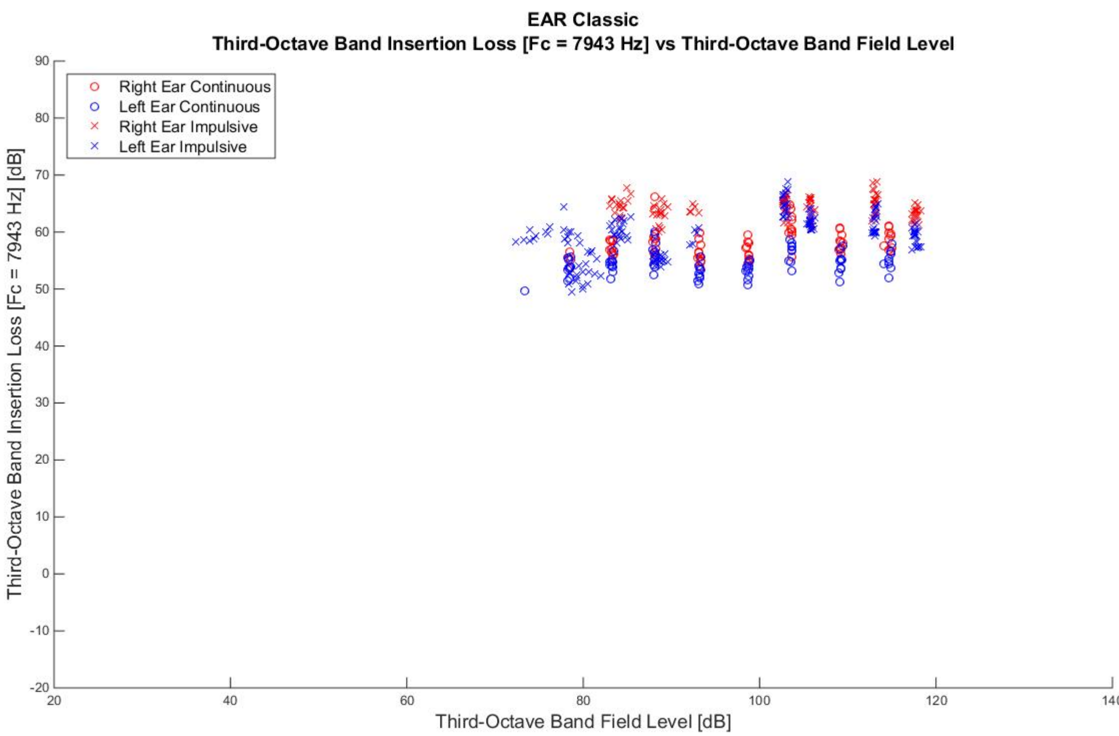

Figure 11. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

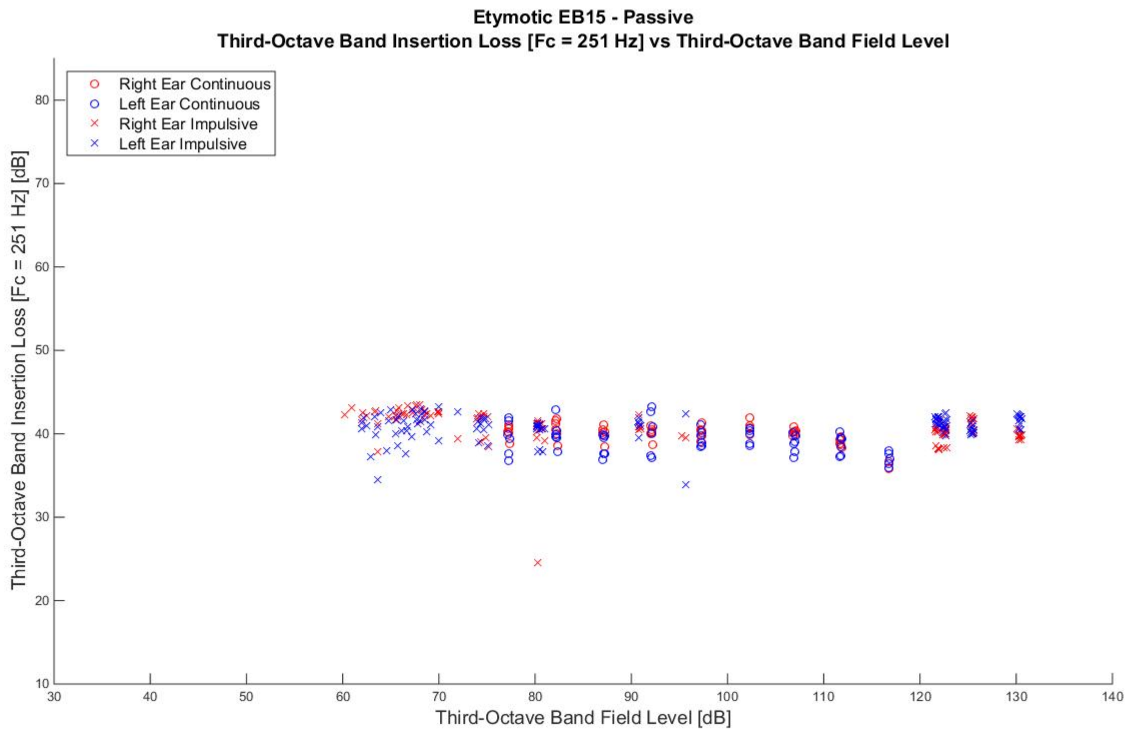

Figure 12. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

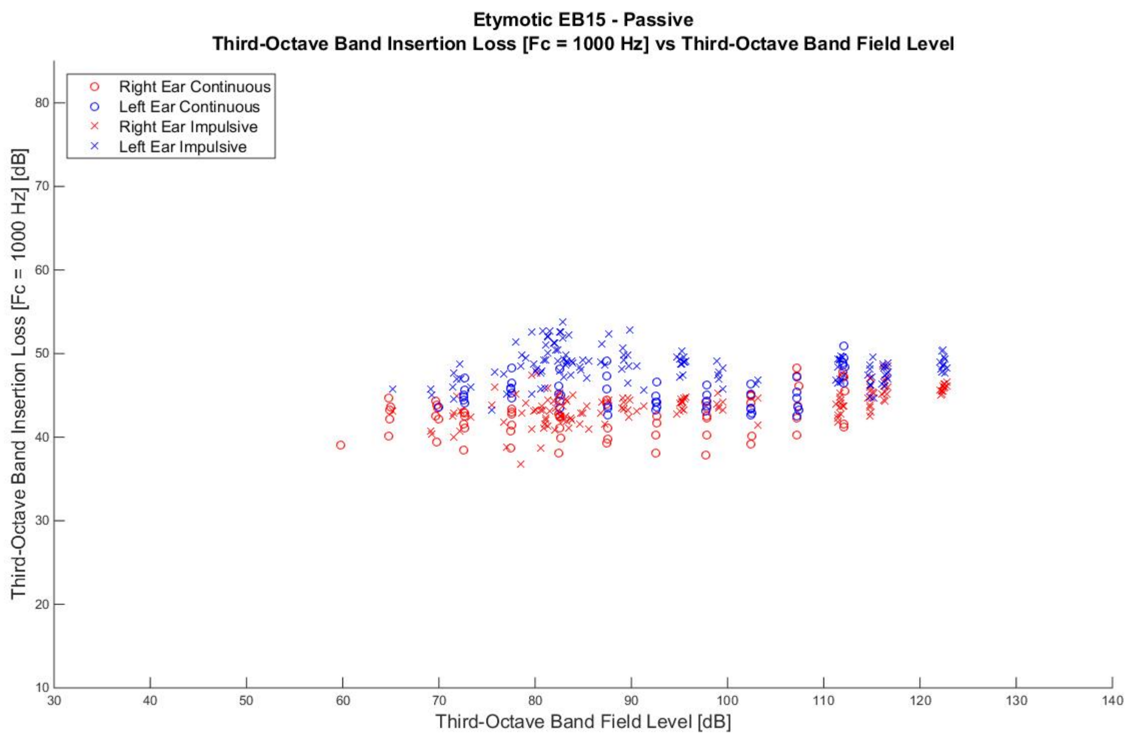

Figure 13. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

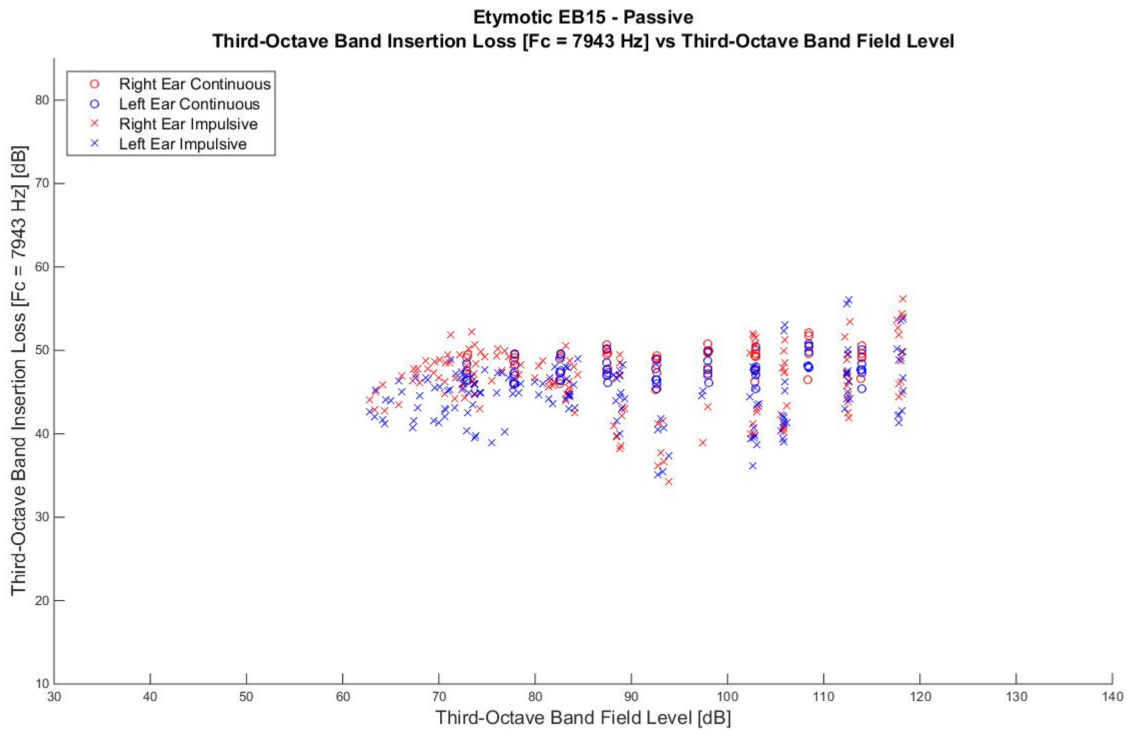

Figure 14. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

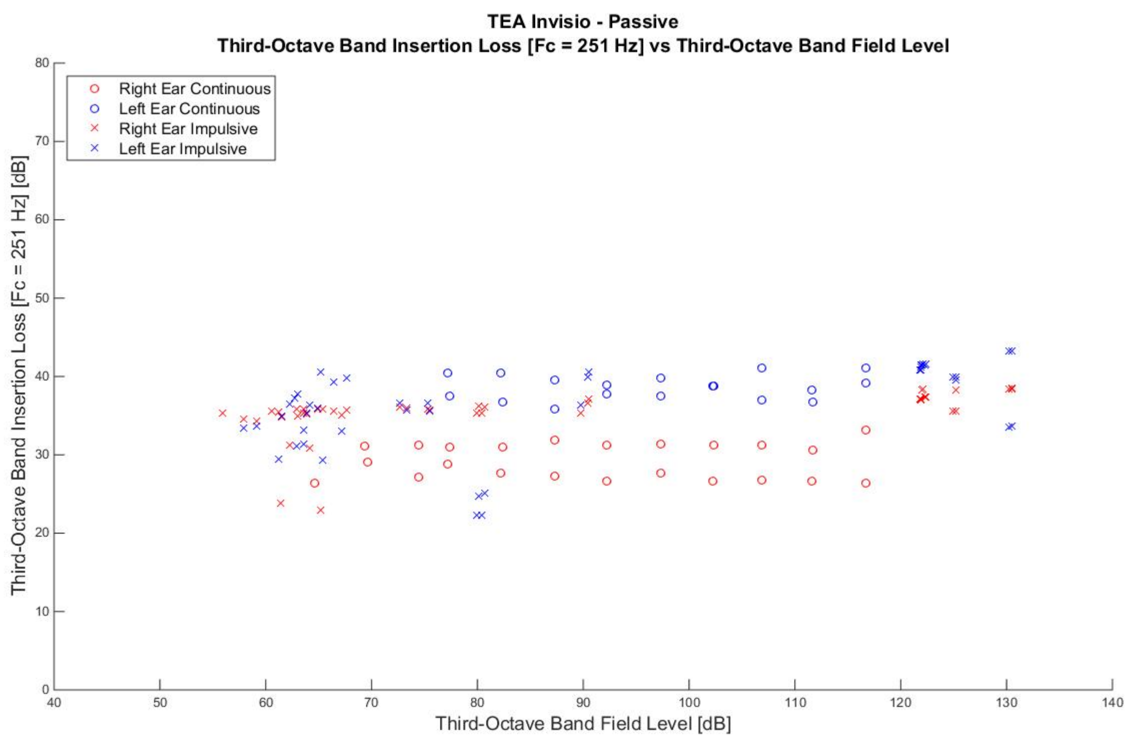

Figure 15. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

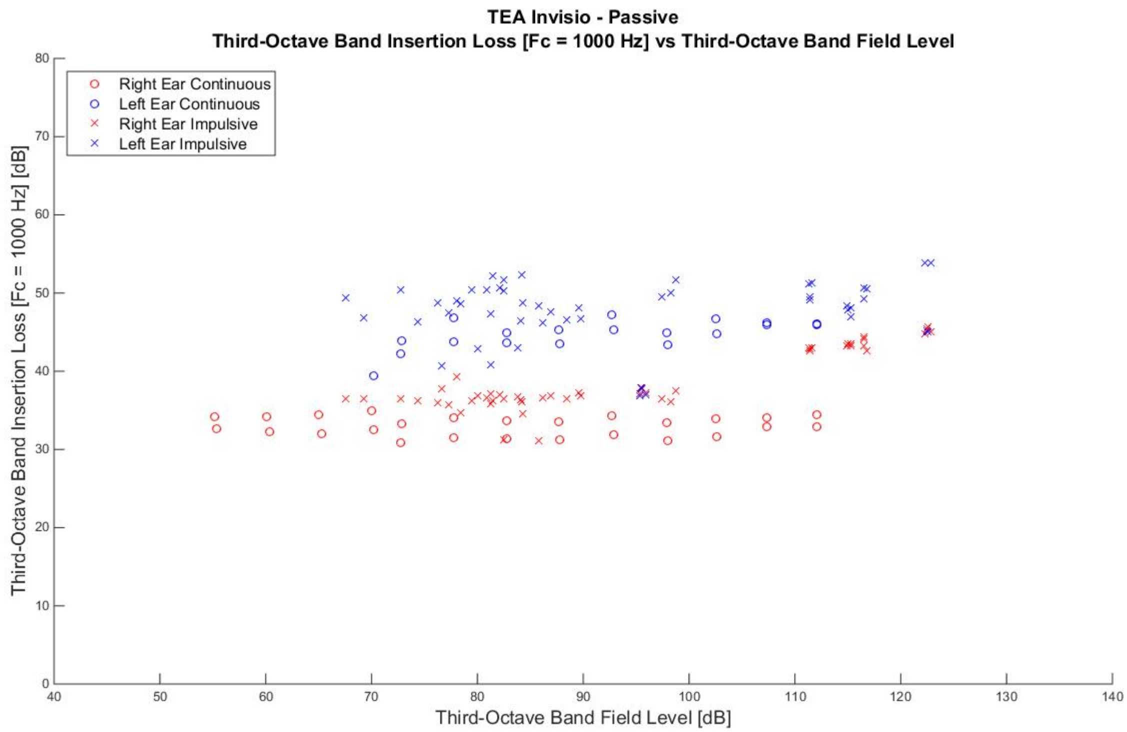

Figure 16. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

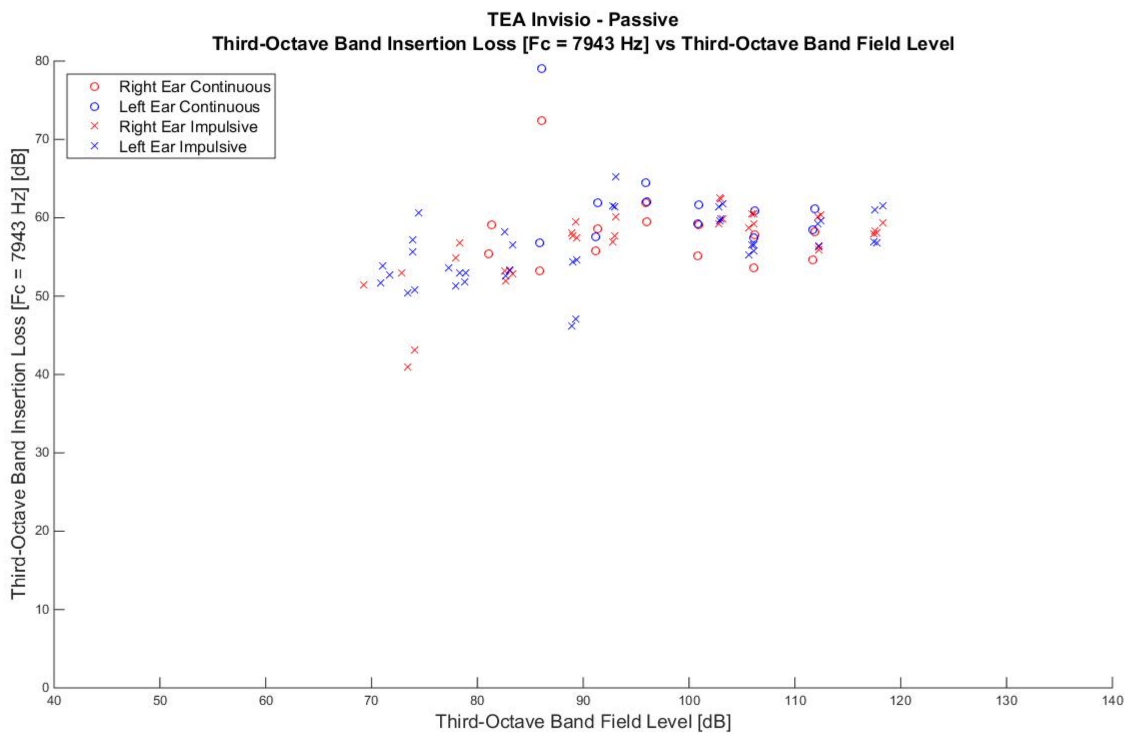

Figure 17. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

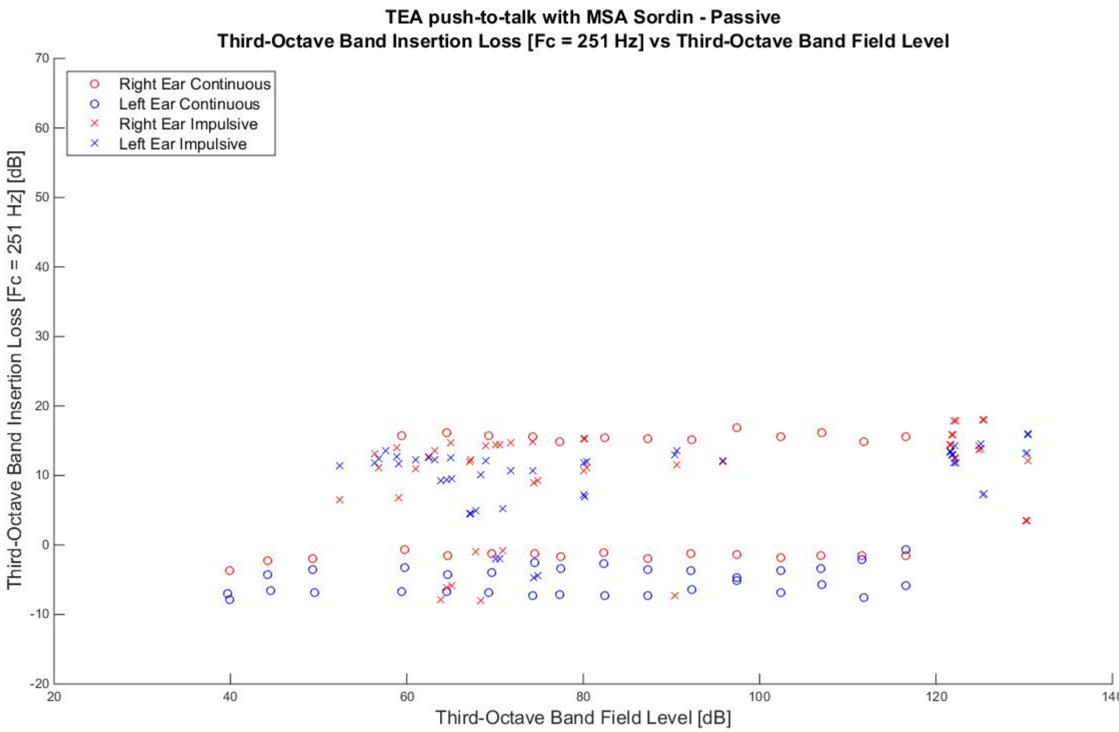

Figure 18. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

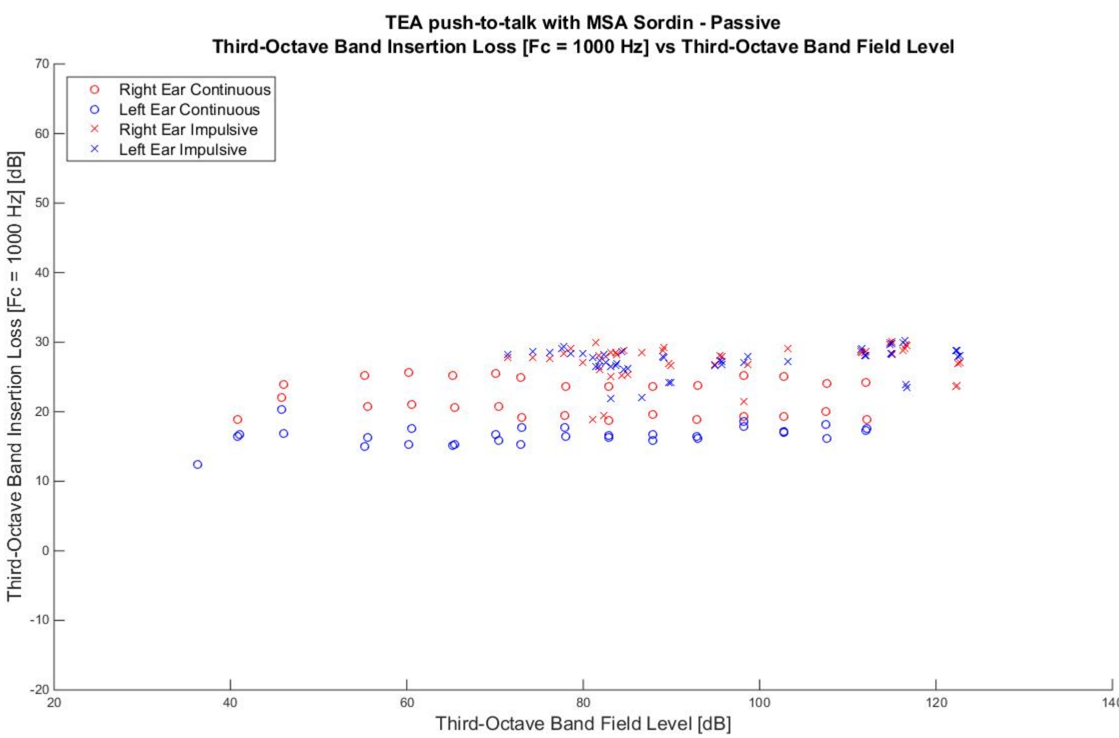

Figure 19. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

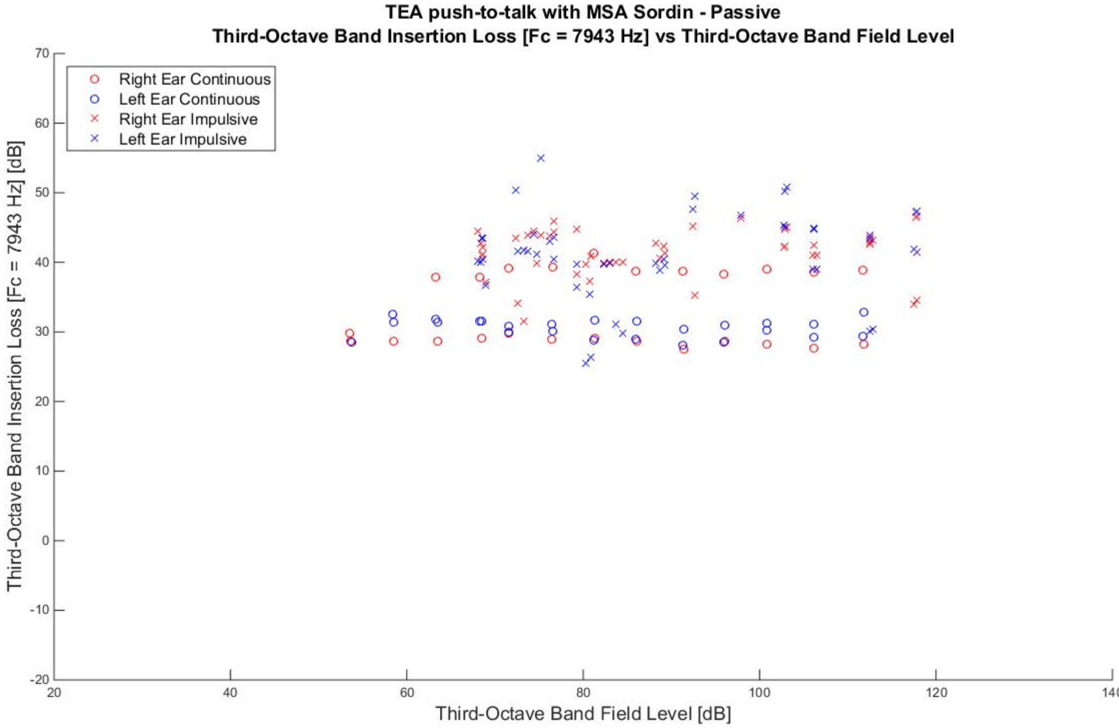

Figure 20. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

Passive nonlinear protector

Figures 21 through 23 show the third octave band insertion loss for the vented Combat Arms Earplug™.

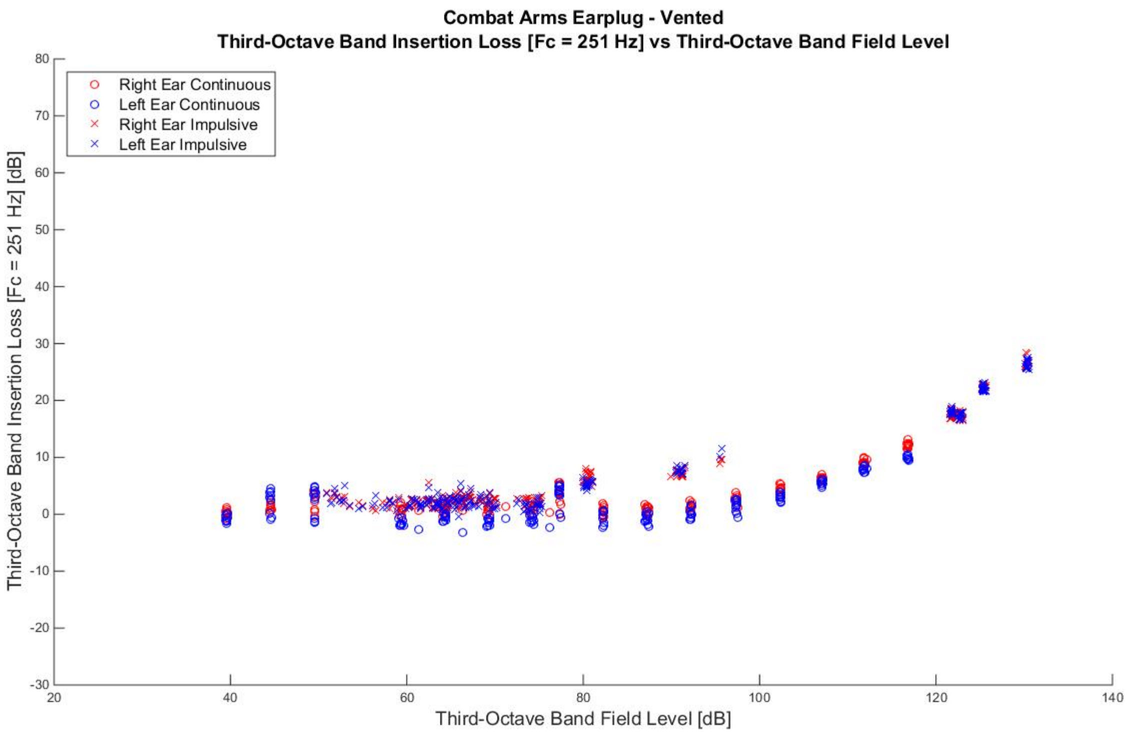

Figure 21. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

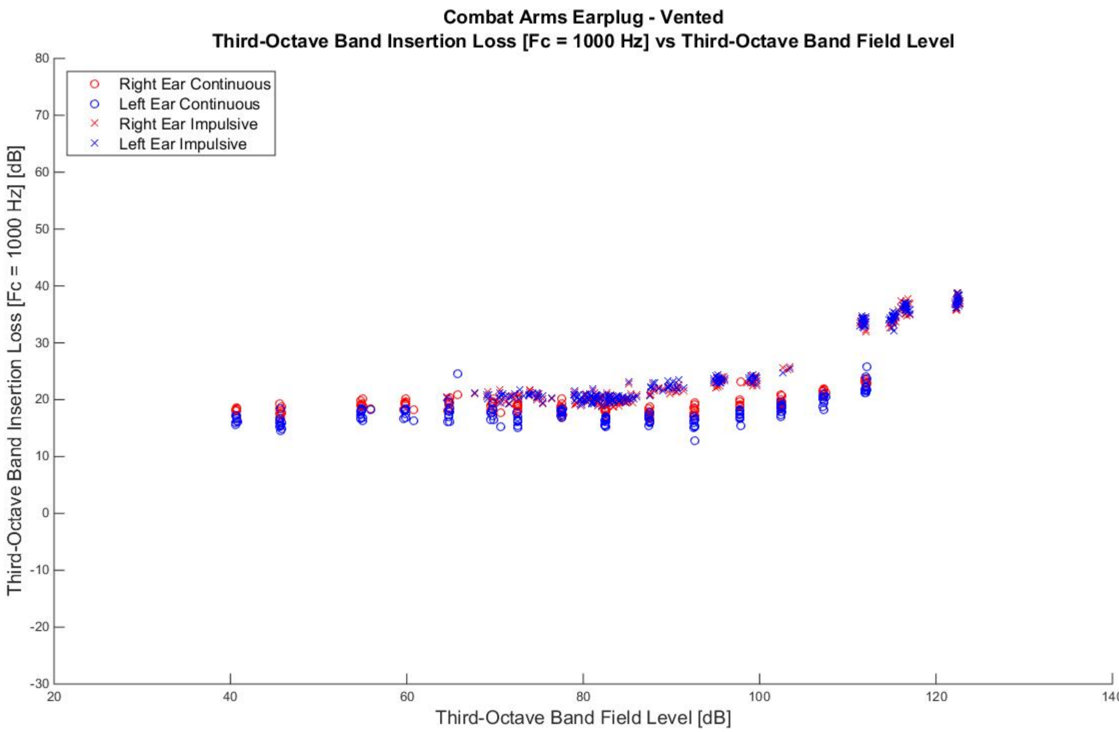

Figure 22. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

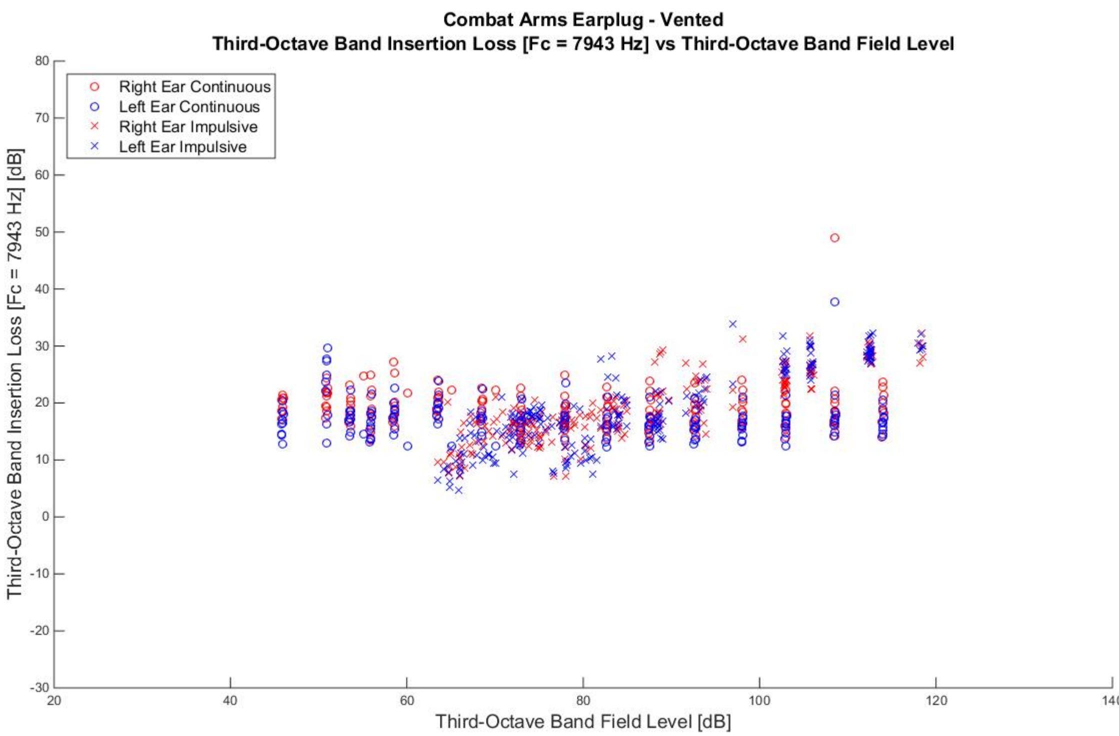

Figure 23. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

Active nonlinear protectors

Figures 24 through 41 show the third-octave band insertion loss values for the active devices tested: the EB15 with high gain, the EB15 with low gain, the TEA Invisio® with high gain (gain 8), the TEA Invisio® with low gain (gain 1), the MSA Sordin with high gain (gain 8), and the MSA Sordin with low gain (gain 1).

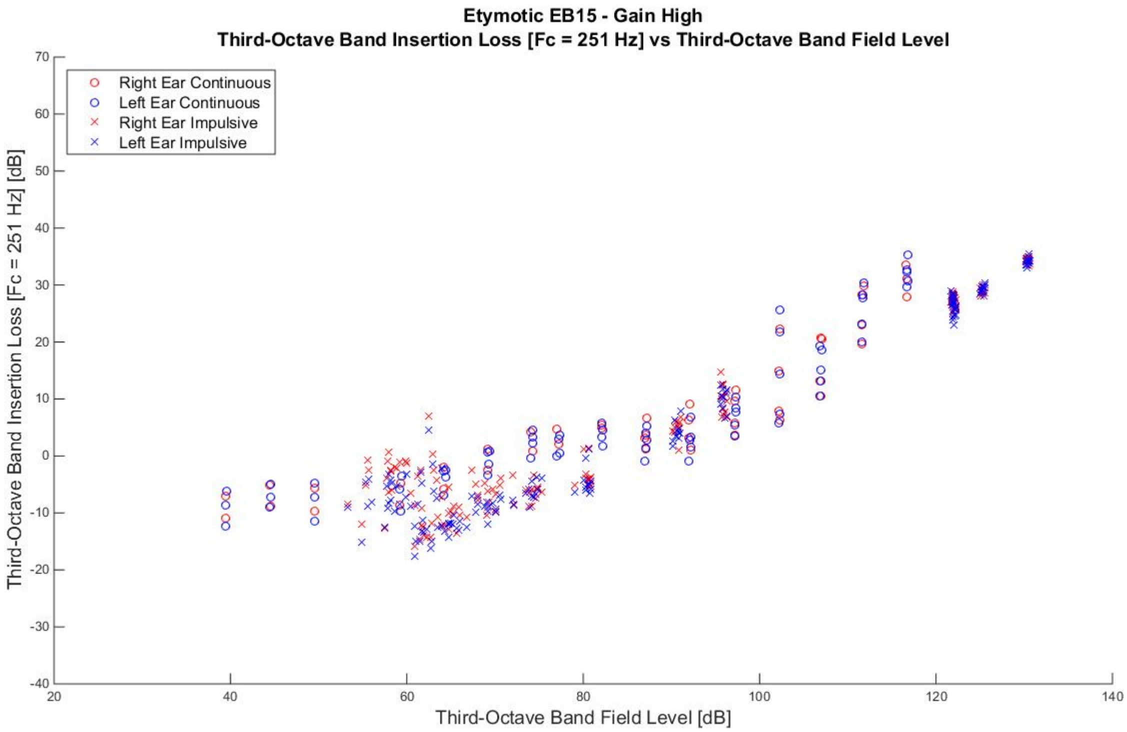

Figure 24. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

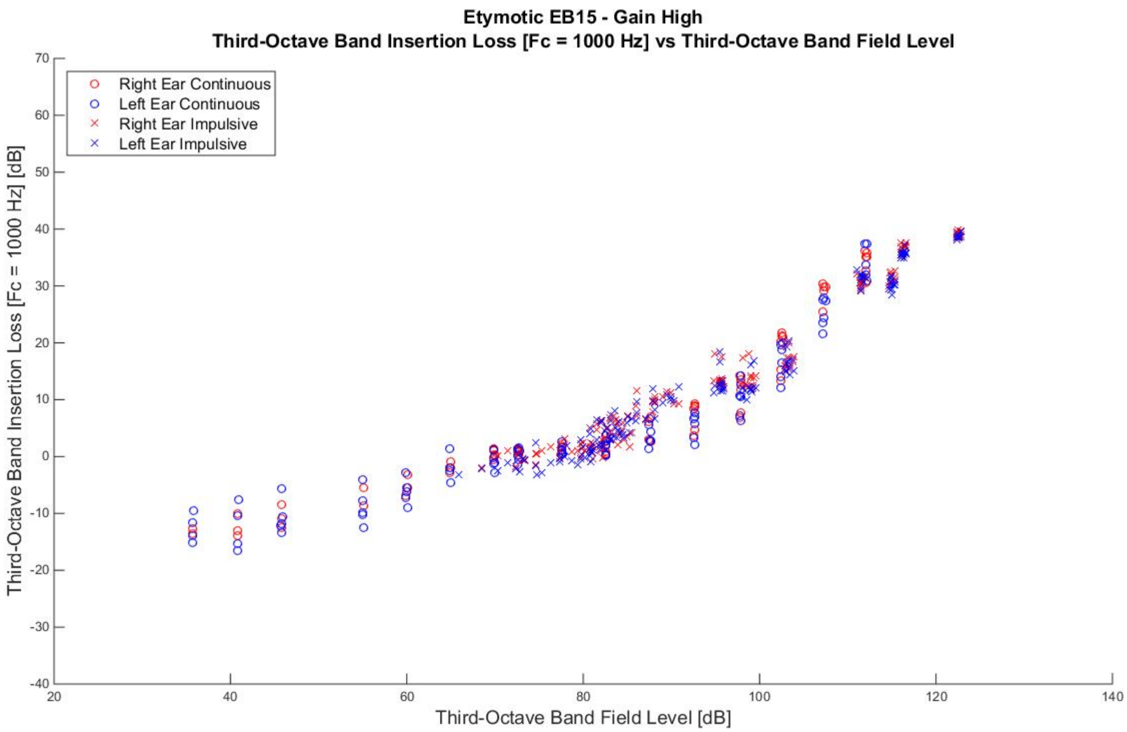

Figure 25. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

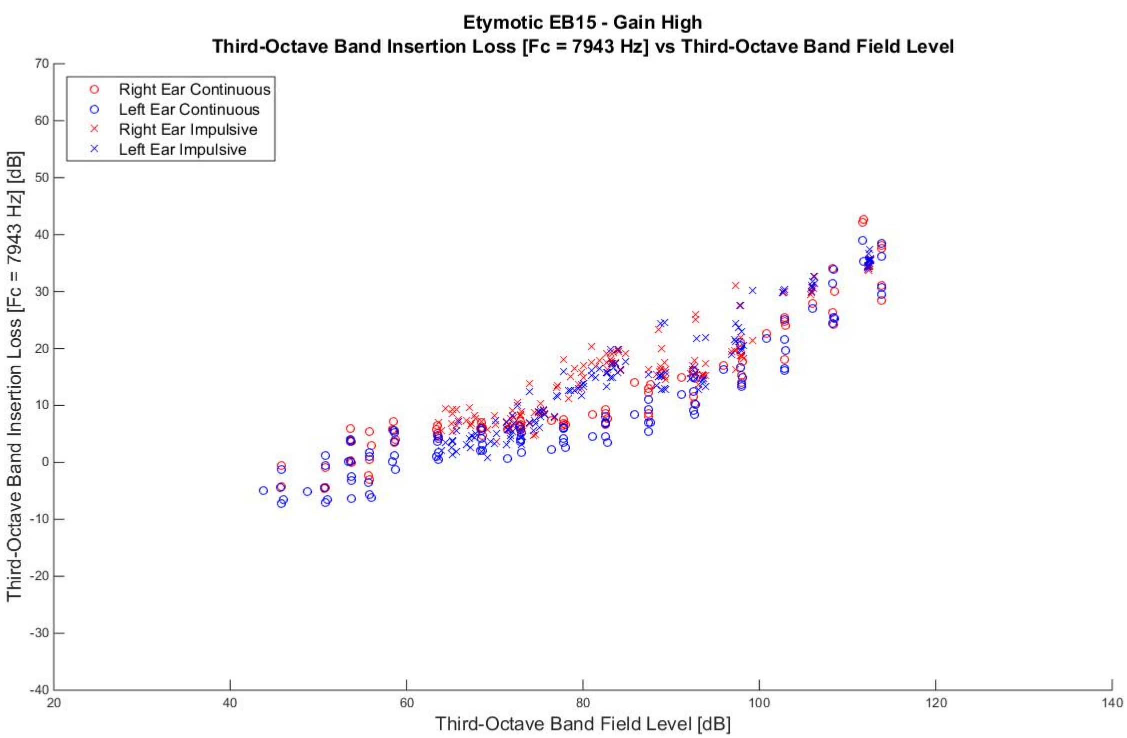

Figure 26. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

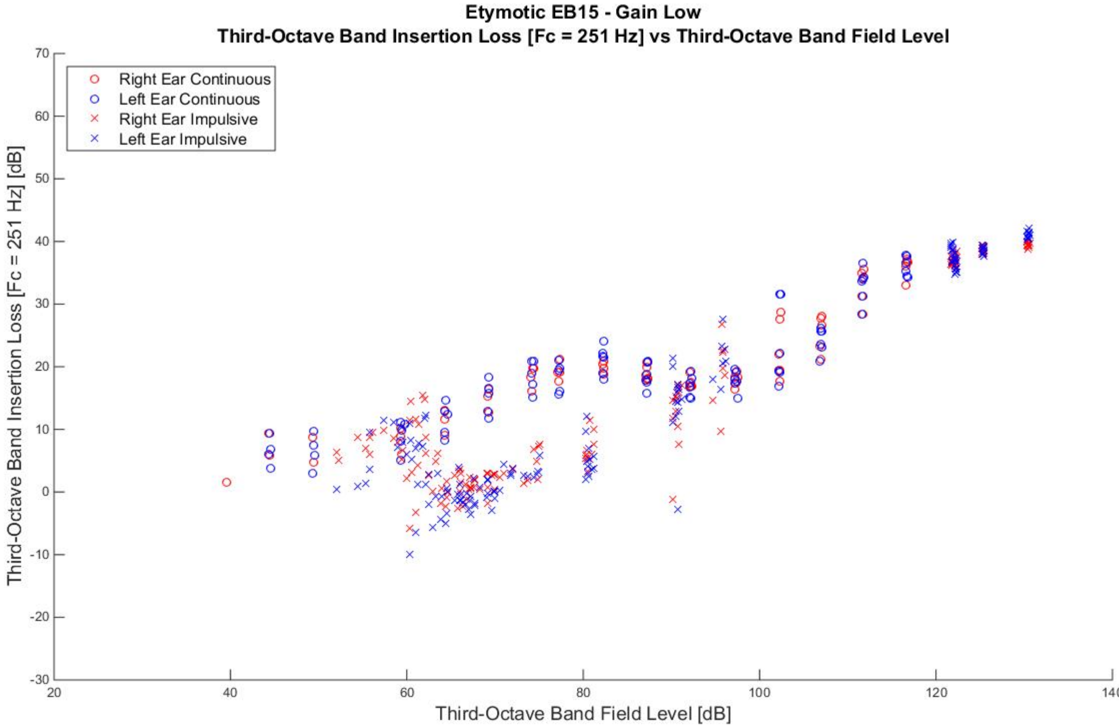

Figure 27. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

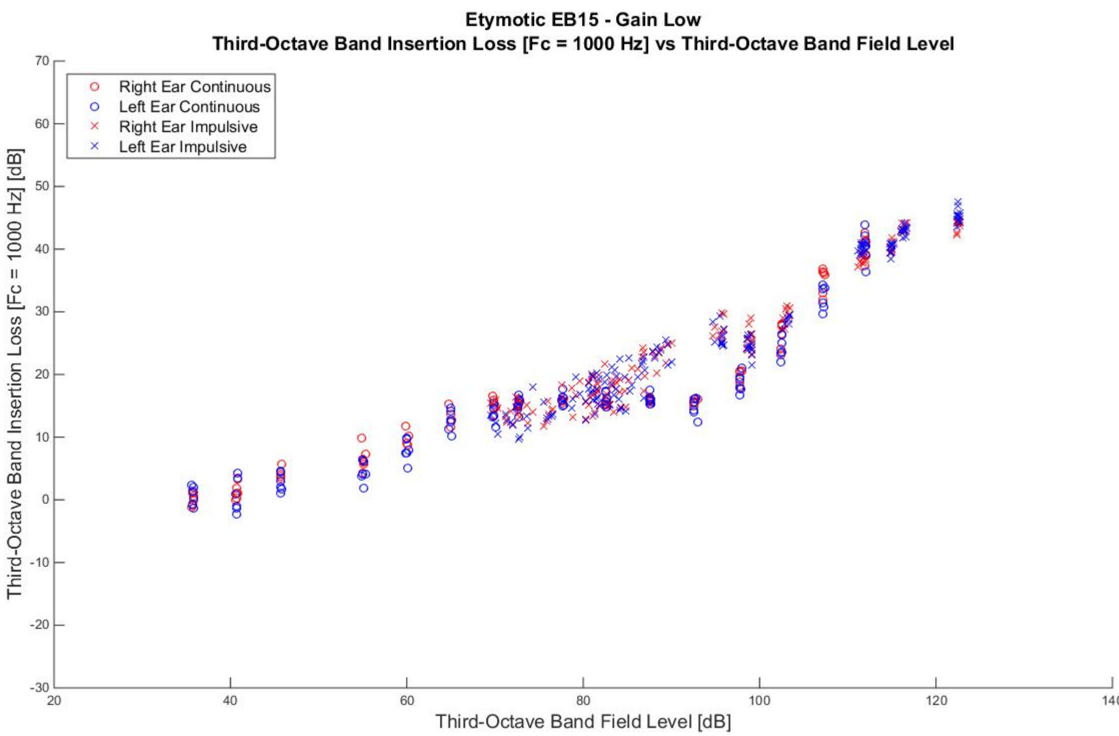

Figure 28. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

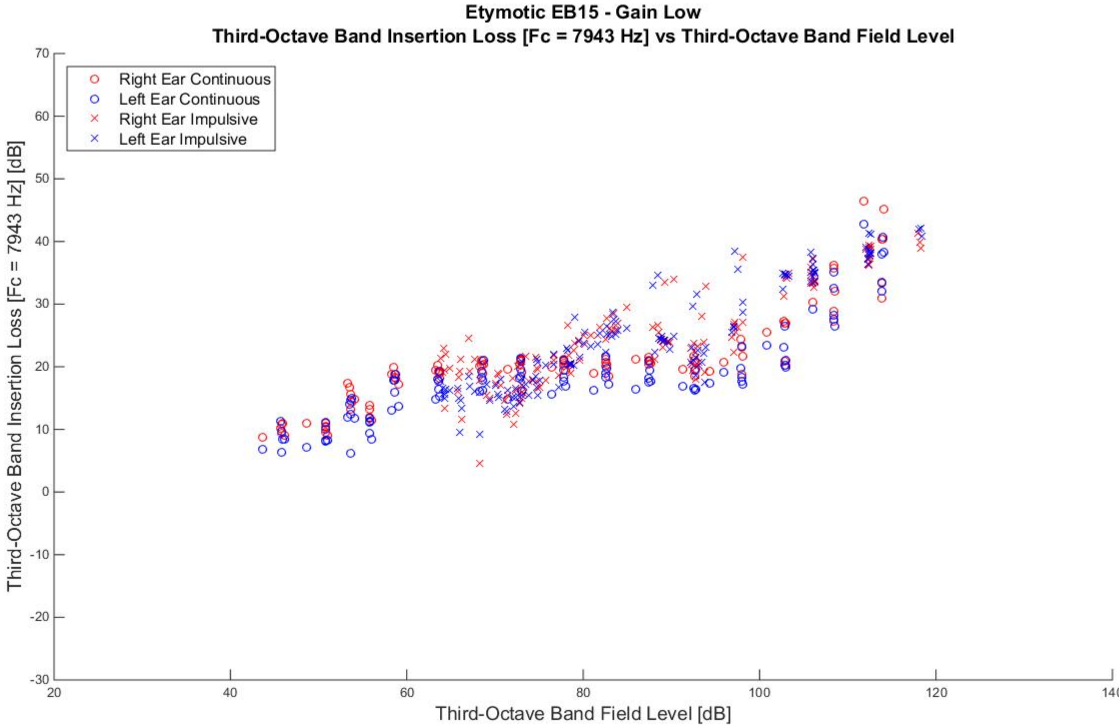

Figure 29. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

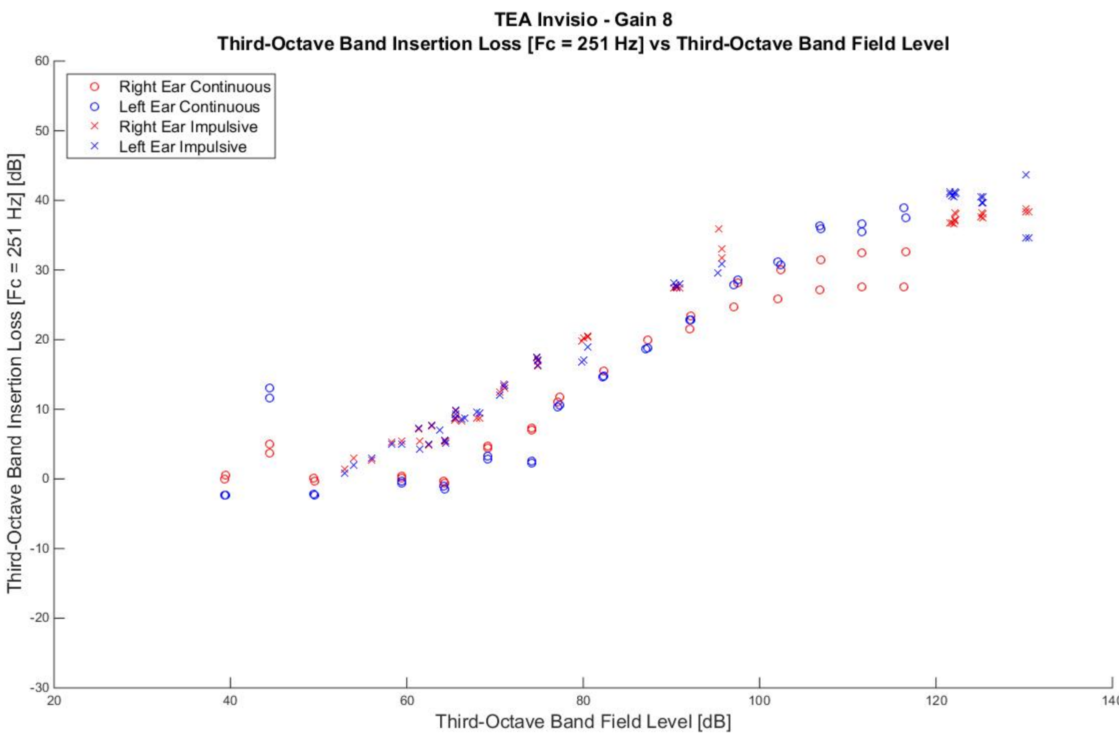

Figure 30. Invisio® - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

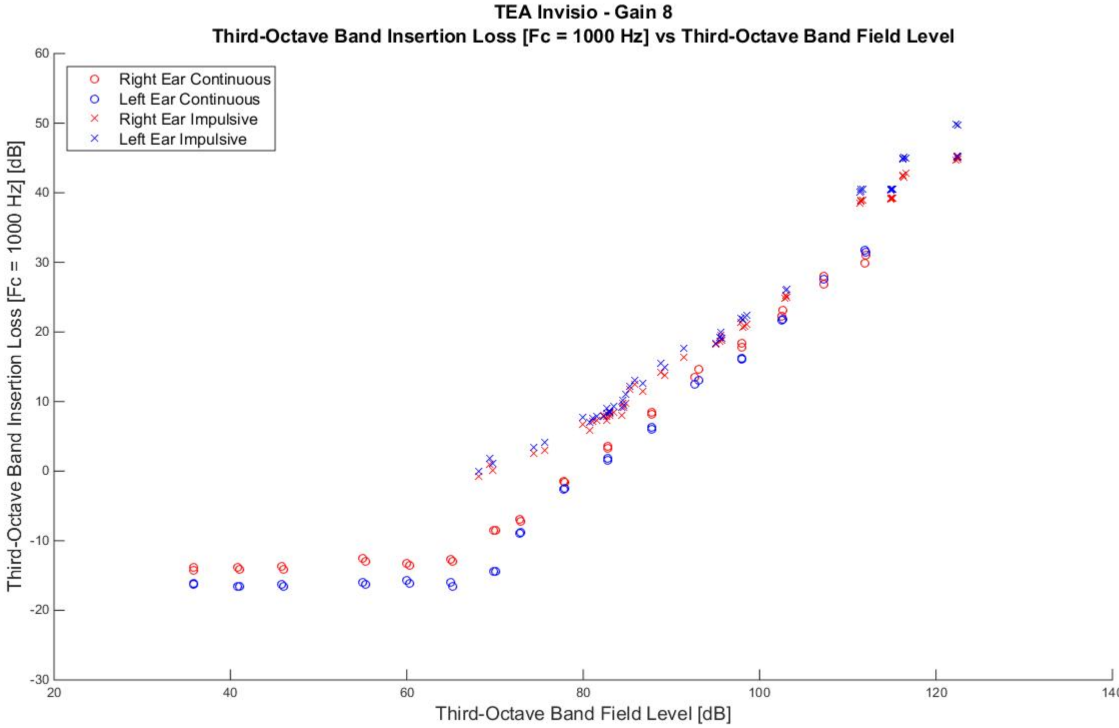

Figure 31. Invisio® - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

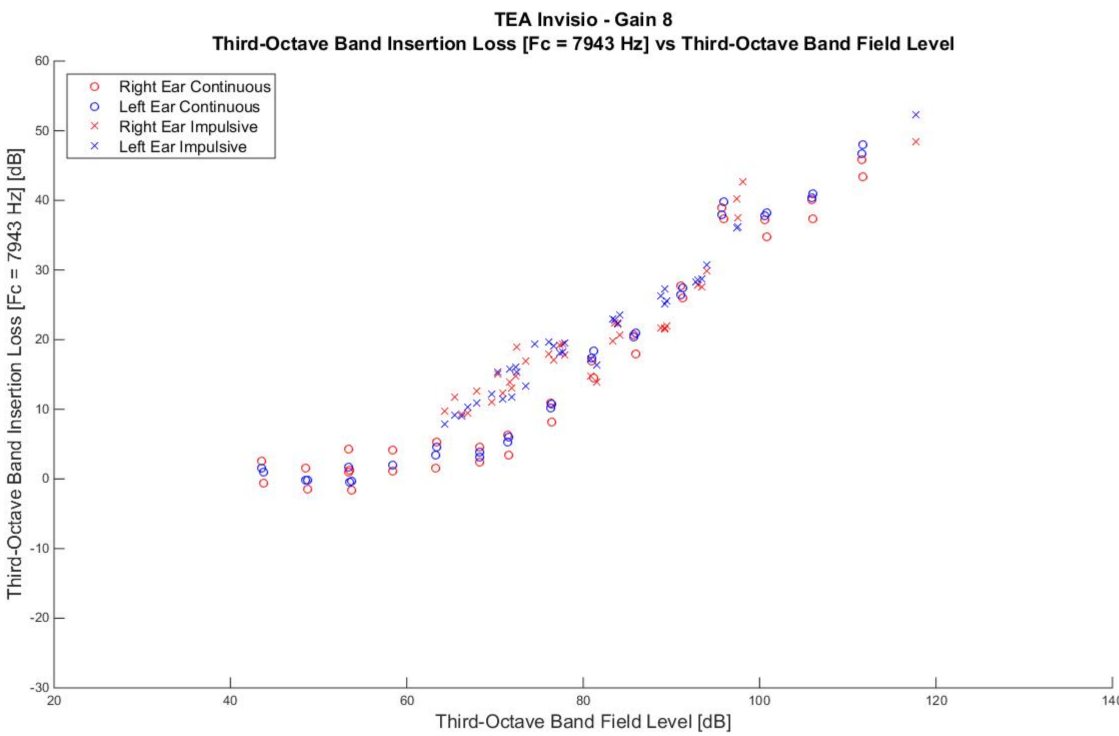

Figure 32. Invisio® - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

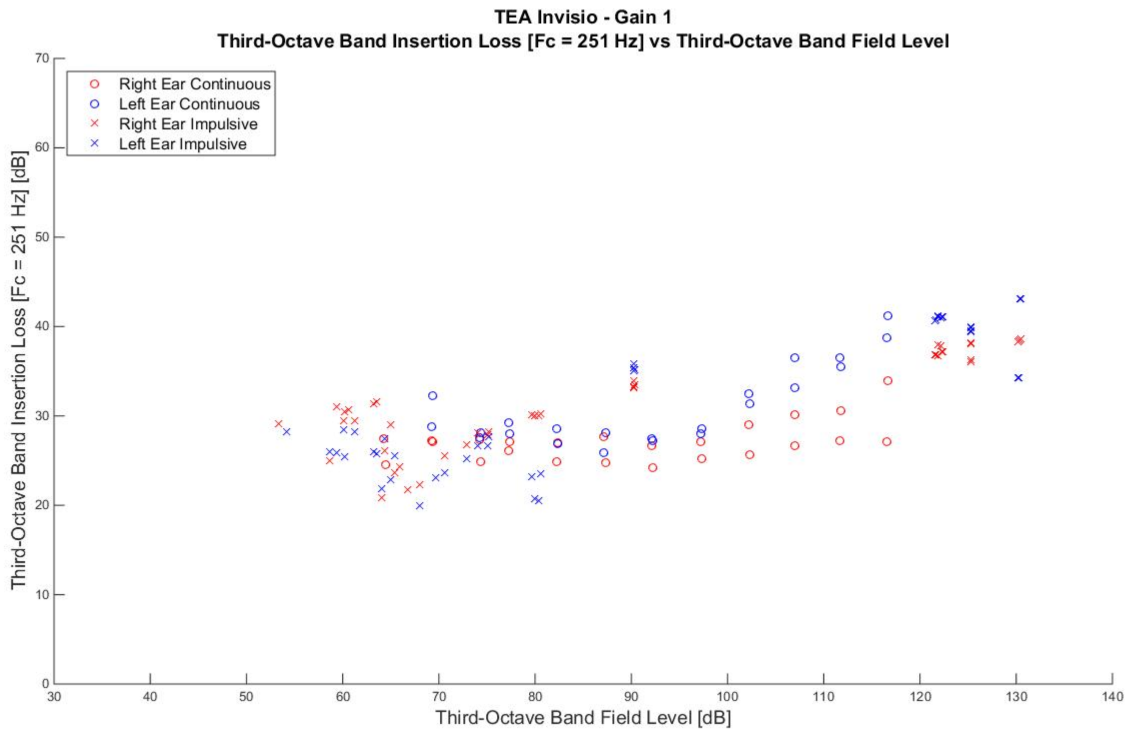

Figure 33. Invisio® - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

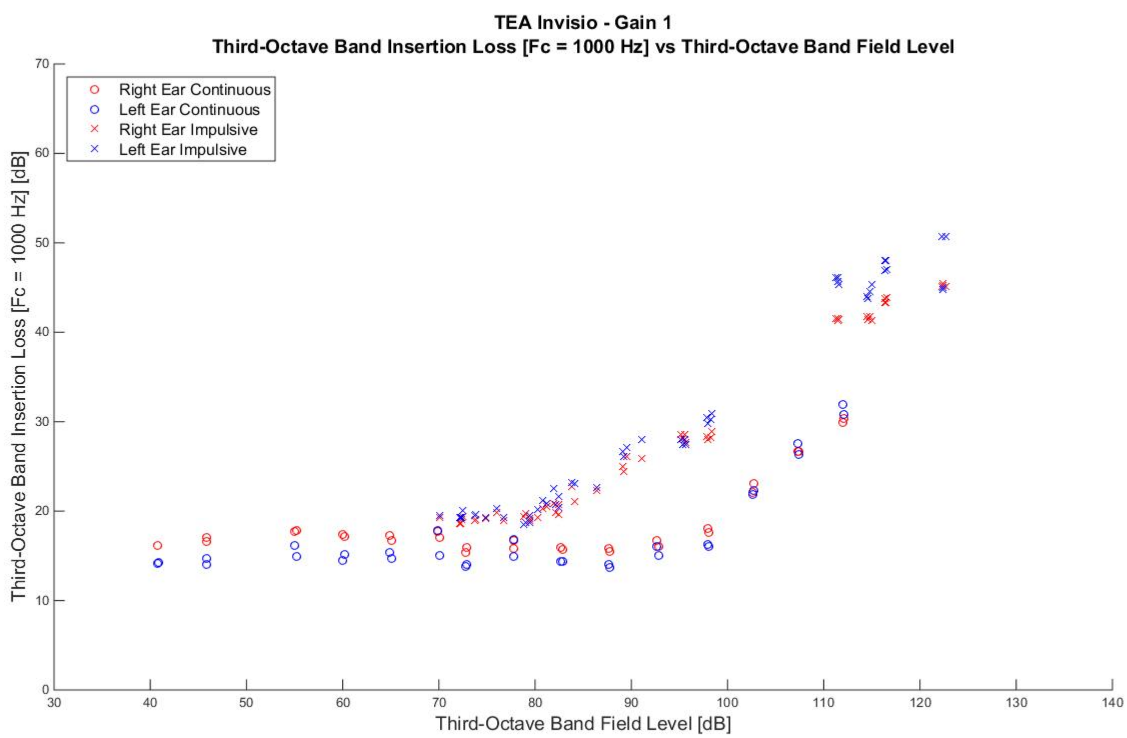

Figure 34. Invisio® - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

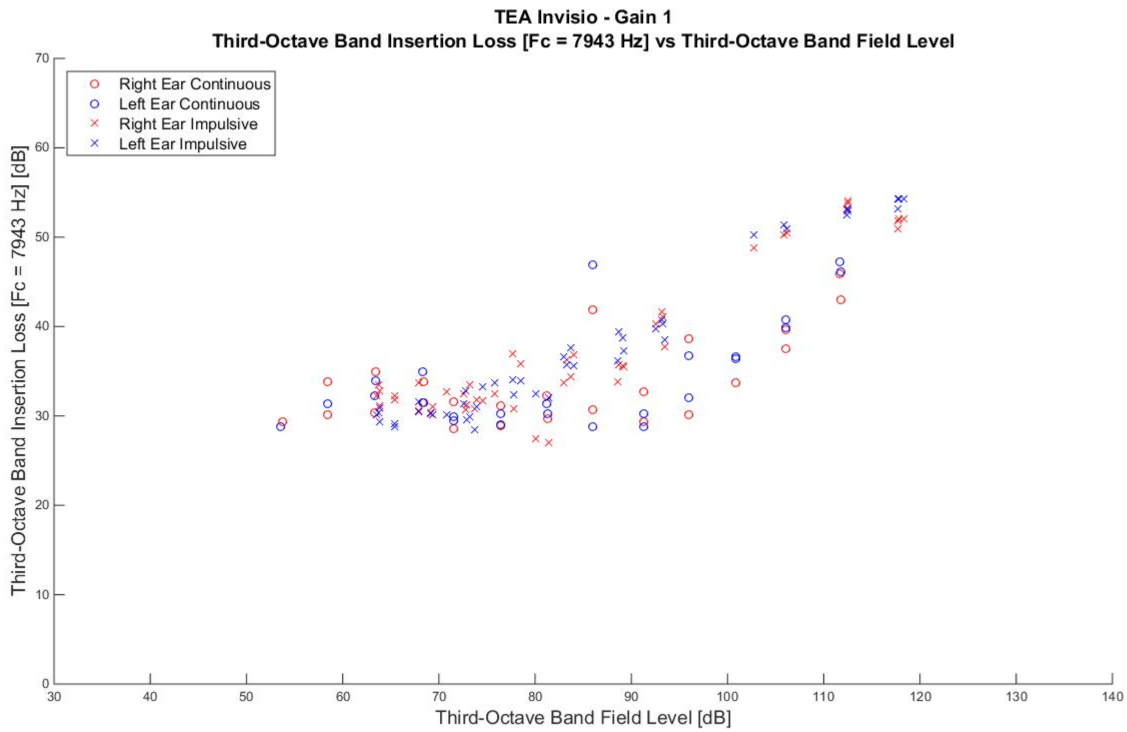

Figure 35. Invisio® - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

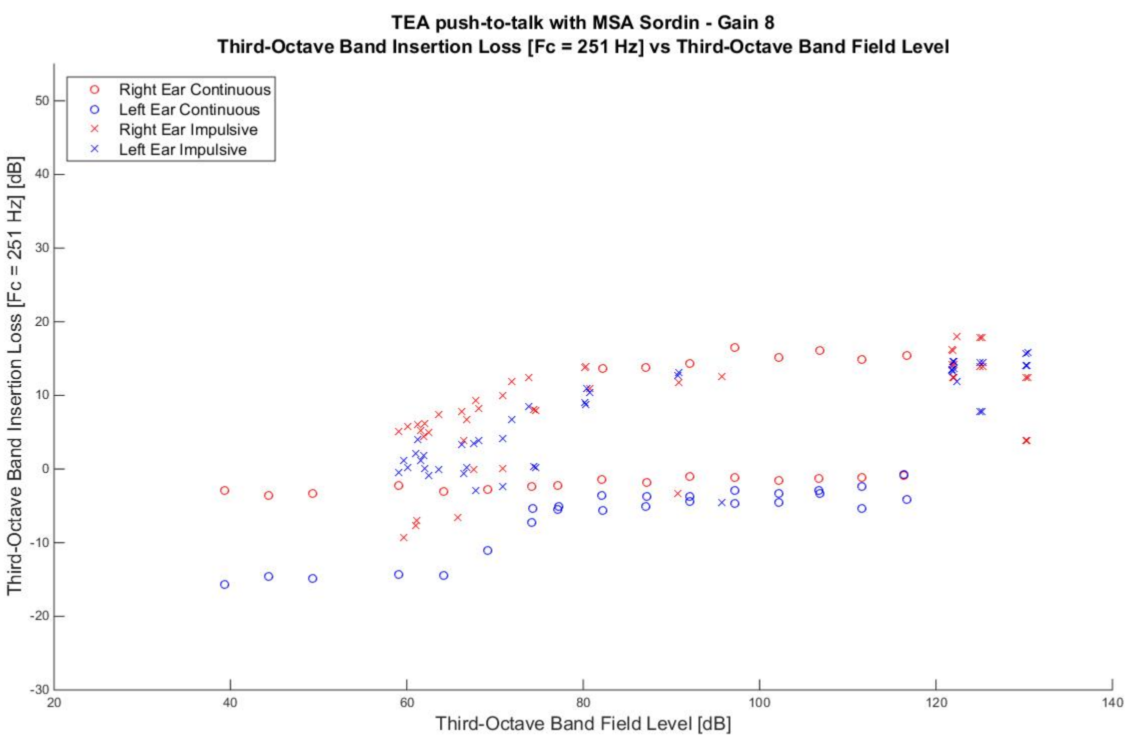

Figure 36. MSA Sordin - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

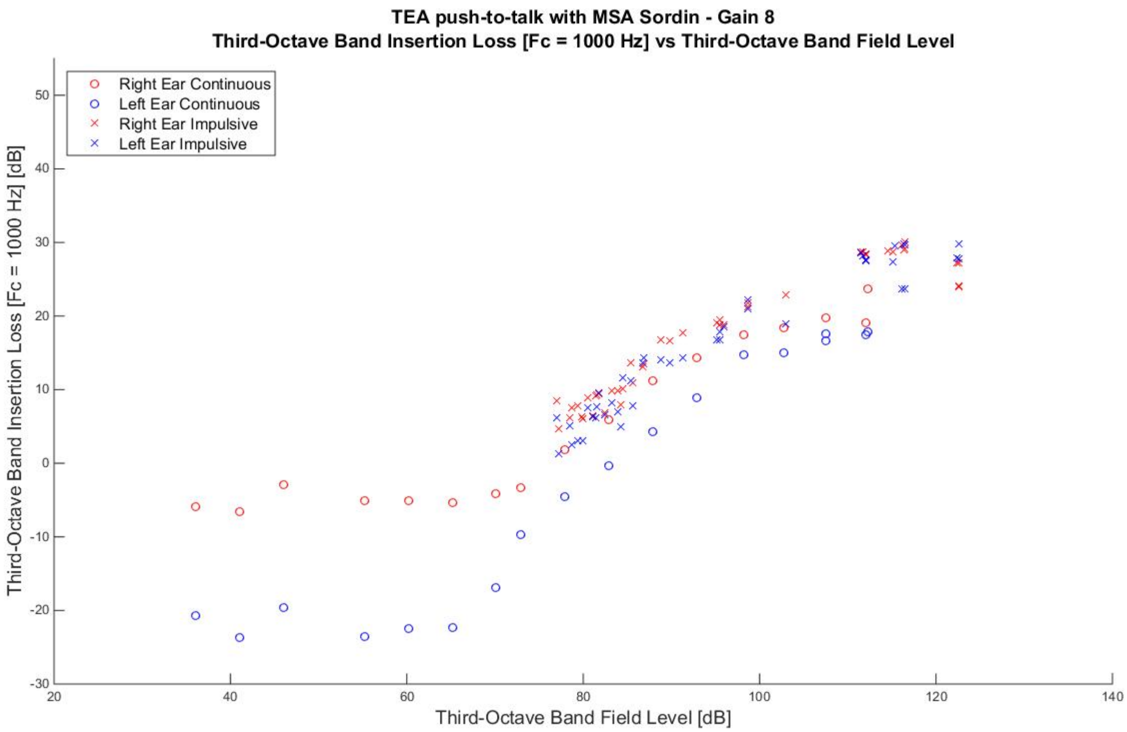

Figure 37. MSA Sordin - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

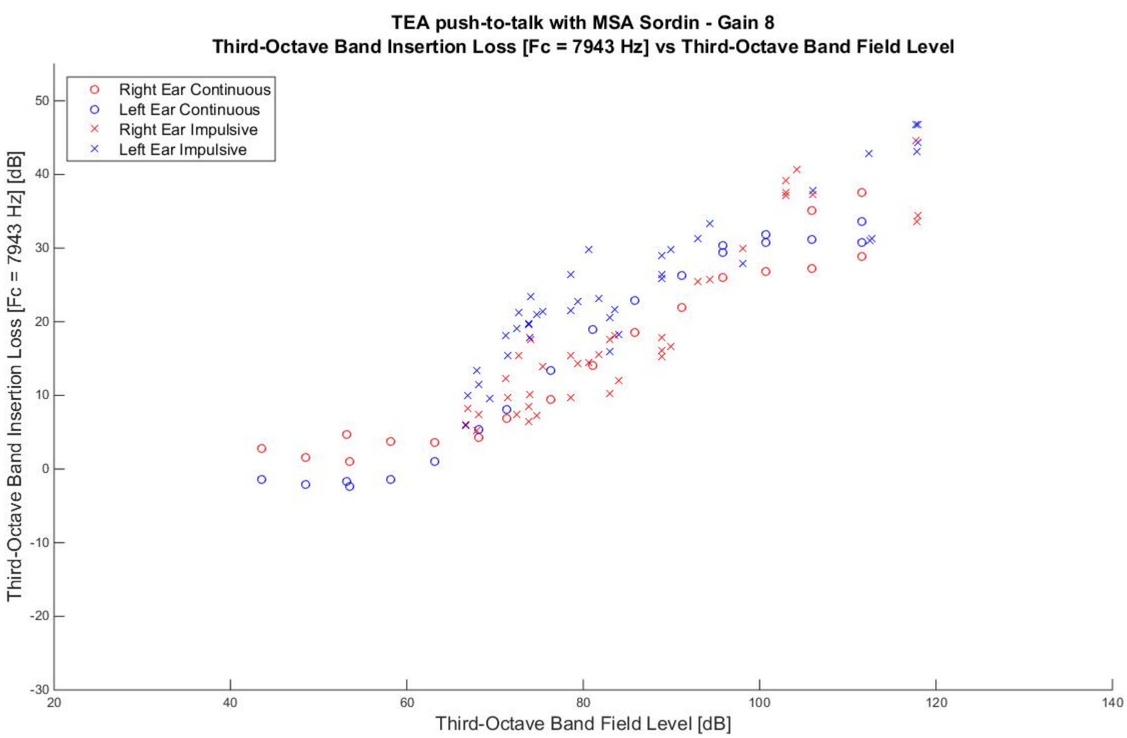

Figure 38. MSA Sordin - gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

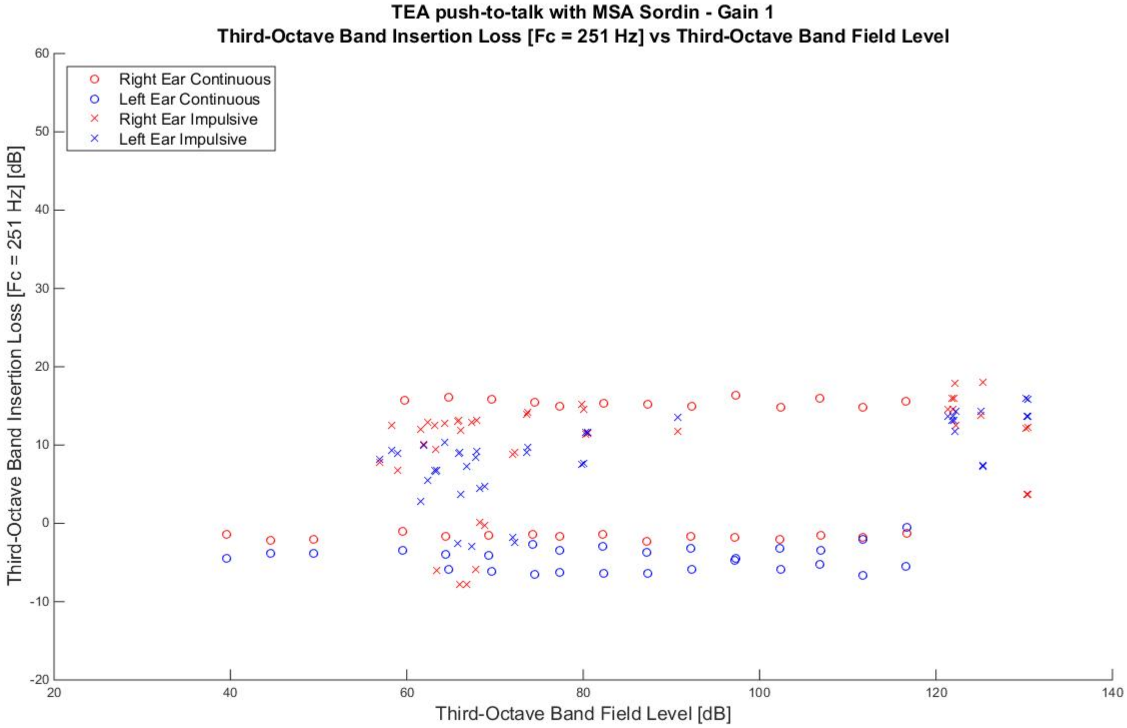

Figure 39. MSA Sordin - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

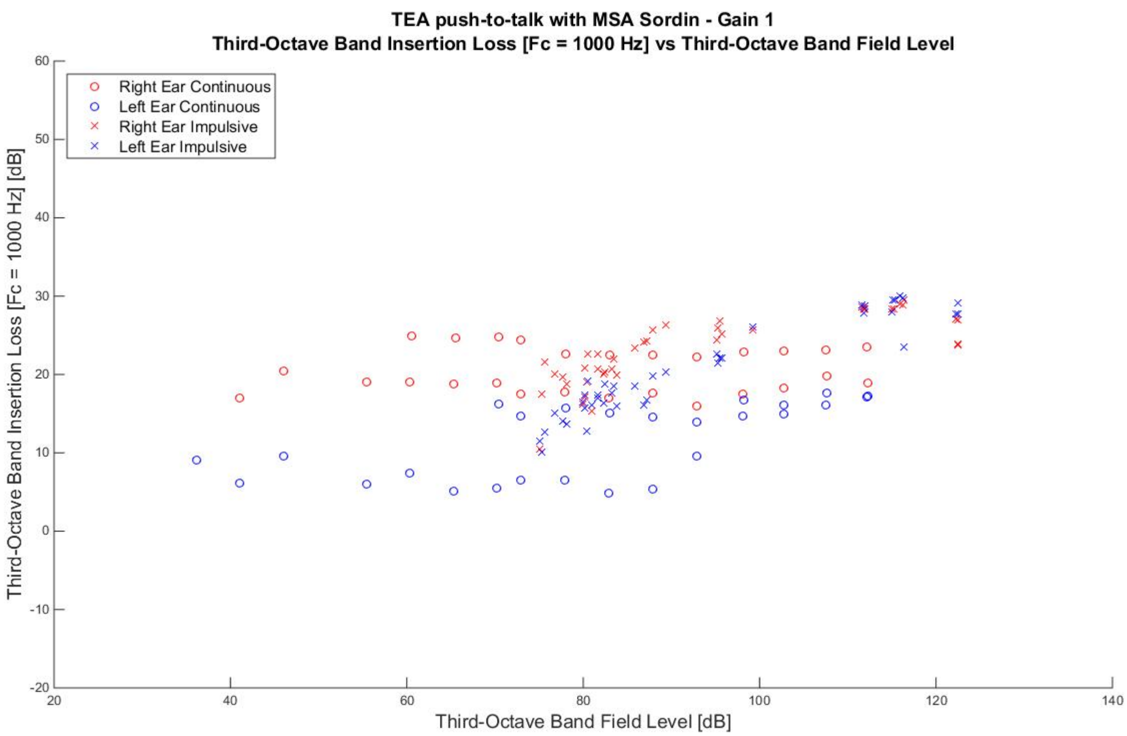

Figure 40. MSA Sordin - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

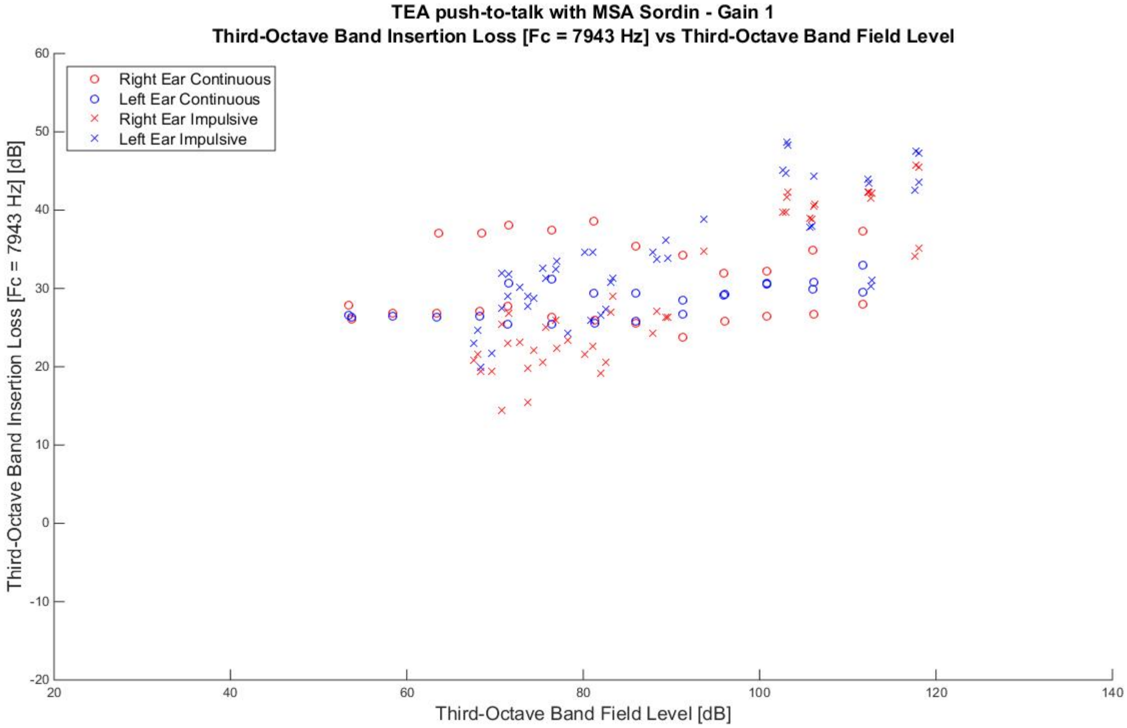

Figure 41. MSA Sordin - gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

Discussion

The results for the passive linear protectors indicate that the insertion loss in a given third-octave band does not appear to vary greatly with respect to the incident SPL. Furthermore, in most of the cases shown, the HPDs do not appear to behave very differently in continuous noise than in impulsive noise. The EAR Classic™, however, appears to provide more insertion loss for impulsive noise than continuous noise. This increase may, however, be a result of wear on the plugs. Only 5 samples of the EAR Classic™ were used for all of the testing, meaning that the plugs were fit repeatedly. Guidance for most expandable foam plugs is to use them once or twice before disposing. The change in insertion loss values may result from the plugs wearing out over the course of testing (the impulsive noise measurements were conducted before the continuous noise measurements). These results indicate that variable insertion loss likely does not need to be considered for passive linear devices over the range of SPLs tested. It is possible that SPLs outside the tested range could have different results.

The results for the active and passive nonlinear protectors show that the insertion loss tends to increase with increasing SPL. The vented Combat Arms Earplug™ increased approximately 40 dB in the 251 Hz third-octave band between 80 and 130 dB field level, while the increase in the 1000 Hz band across the same range is 20 dB. The 7943 Hz band is less consistent. The active plugs showed an even greater change in insertion loss, in some cases increasing 60 dB across a similar range of incident SPLs. Also, while impulse and continuous noise data do not seem to precisely align for this set of measurements, the change in insertion loss appears for both

continuous and impulsive noise measurements and should be considered regardless of the type of noise exposure.

The results from the MSA Sordin headset appear less consistent than those from insert plugs. This variability may partially be a result of the manner in which the earmuffs fit to the head form. At times, there are significant differences in insertion loss between the right and left ears of the head form, especially for the continuous noise measurements. This may be the result of one ear cup fitting the head form better than the other.

Regression analysis

In order to examine the relationships between the measured insertion loss values and the incident sound levels, a regression analysis was performed. A logistic function was fit to the data in order to predict the third-octave band insertion loss based on an incident third-octave band SPL. A logistic function is a curve that asymptotes between two possible values and has the form:

$$f(x) = L + \frac{U - L}{(1 + e^{-K(x-M)})}$$

where *L* is the lower asymptote, *U* is the upper asymptote, *K* is the steepness of the curve, and *M* is the midpoint (on the *x* axis) where

$$f(M) = L + \frac{U - L}{2}$$

In this case, *x* would be the third octave band field level, while $f(x)$ would be the third-octave band insertion loss. A logistic function was chosen because of its behavior when extrapolating to values outside the measured range, the result will never be above the upper asymptote or below the lower asymptote. The fitting was performed using the nonlinear regression functions in the MATLAB Statistics and Machine Learning Toolbox. Table 1 shows the R-squared values from the regression in each of the 31 bands. Table entries with cross hatching indicate instances where the R-squared value was below 0.75.

Table 1 indicates that the regression analysis reasonably describes the behavior of some of the nonlinear devices, especially in the frequency ranges between 200 Hz and 1 kHz. Using this regression technique, it is straightforward to examine the relationship between insertion loss and gain for the active protectors. Figures 42 through 47 show the regression predicted insertion loss values within the 251, 1000, and 7943 Hz bands for the EB15 and TEA Invisio® for all of the devices gain settings (as well as a regression based on the passive measurements). As expected, the lower gain settings resulted in higher insertion loss values, with most of the values seeming to approach the maximum value of the passive setting as SPL increased.

It is worth noting that this regression analysis was performed without any attempt to identify or remove statistical outliers. Additionally, no attempt was made to bound the results of this analysis (i.e., limit the values of the upper and lower asymptote to reasonable values

demonstrated by the measurements, etc.). Both techniques may be advisable if attempting to use a regression analysis as a predictor of actual performance.

Table 1.
Regression R-squared values.
Third-octave band field level vs. third-octave band insertion loss

	CAEP Vented	EB15 Gain High	EB15 Gain Low	TEA Invisio® Gain 8	TEA Invisio® Gain 1	MSA Sordin Gain 8	MSA Sordin Gain 1
19 Hz	0.25	0.85	0.78	0.15	0.06	0.00	0.00
25 Hz	0.03	0.64	0.65	0.10	0.00	0.02	0.00
31 Hz	0.01	0.53	0.56	0.27	0.18	0.06	0.03
39 Hz	0.04	0.63	0.71	0.34	0.18	0.09	0.16
50 Hz	0.09	0.67	0.74	0.45	0.24	0.11	0.13
63 Hz	0.27	0.62	0.72	0.37	0.27	0.22	0.24
79 Hz	0.10	0.79	0.80	0.51	0.25	0.12	0.17
100 Hz	0.57	0.86	0.81	0.56	0.24	0.12	0.16
125 Hz	0.77	0.87	0.83	0.59	0.15	0.05	0.05
158 Hz	0.93	0.90	0.86	0.65	0.11	0.14	0.15
199 Hz	0.94	0.91	0.86	0.82	0.42	0.18	0.18
251 Hz	0.94	0.94	0.87	0.94	0.69	0.32	0.21
316 Hz	0.87	0.96	0.90	0.97	0.77	0.51	0.18
398 Hz	0.84	0.95	0.89	0.96	0.86	0.73	0.28
501 Hz	0.93	0.96	0.93	0.99	0.93	0.87	0.35
630 Hz	0.88	0.96	0.92	0.97	0.88	0.90	0.46
794 Hz	0.86	0.95	0.92	0.95	0.84	0.89	0.36
1000 Hz	0.86	0.96	0.94	0.96	0.86	0.89	0.45
1258 Hz	0.73	0.95	0.93	0.96	0.85	0.89	0.52
1584 Hz	0.75	0.92	0.89	0.96	0.89	0.91	0.59
1995 Hz	0.55	0.92	0.88	0.96	0.82	0.89	0.53
2511 Hz	0.37	0.91	0.87	0.94	0.81	0.82	0.49
3162 Hz	0.45	0.95	0.90	0.95	0.83	0.83	0.53
3981 Hz	0.54	0.93	0.88	0.93	0.78	0.86	0.63
5011 Hz	0.57	0.90	0.81	0.90	0.69	0.87	0.54
6309 Hz	0.50	0.86	0.67	0.94	0.73	0.89	0.51
7943 Hz	0.35	0.87	0.77	0.94	0.81	0.85	0.49
10000 Hz	0.29	0.89	0.80	0.91	0.61	0.57	0.34
12589 Hz	0.24	0.79	0.67	0.85	0.48	0.48	0.19
15848 Hz	0.22	0.86	0.77	0.83	0.70	0.31	0.27
19952 Hz	0.24	0.83	0.74	0.94	0.31	0.50	0.23

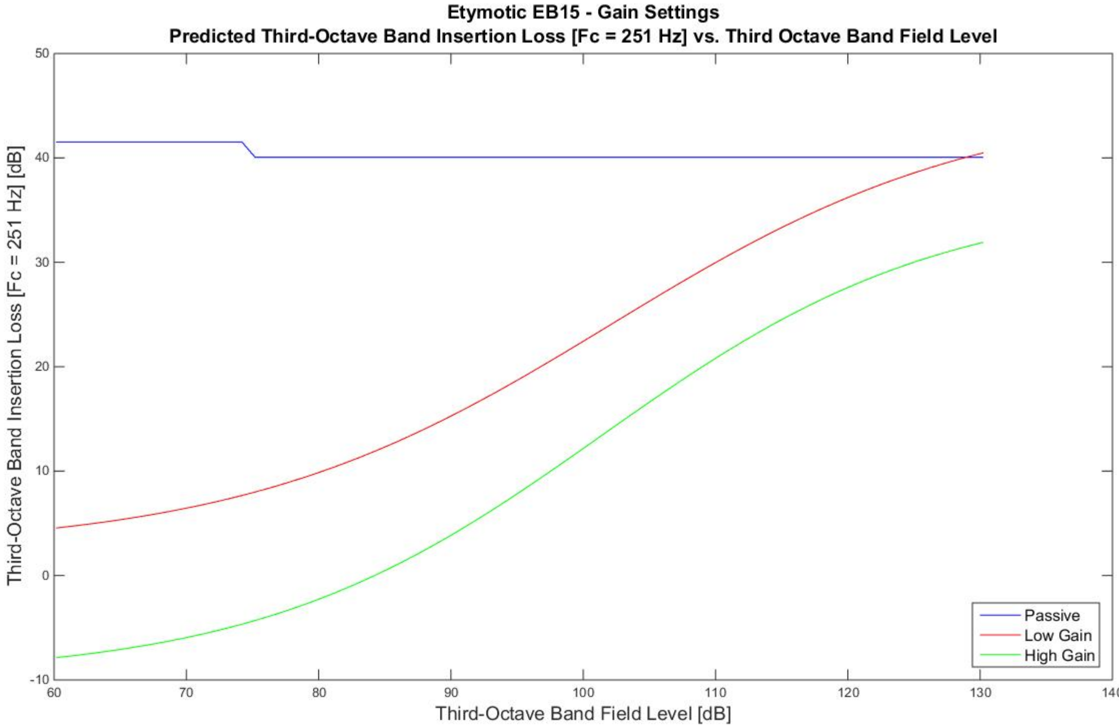

Figure 42. EB15 insertion loss variation based on gain settings - 251 Hz.

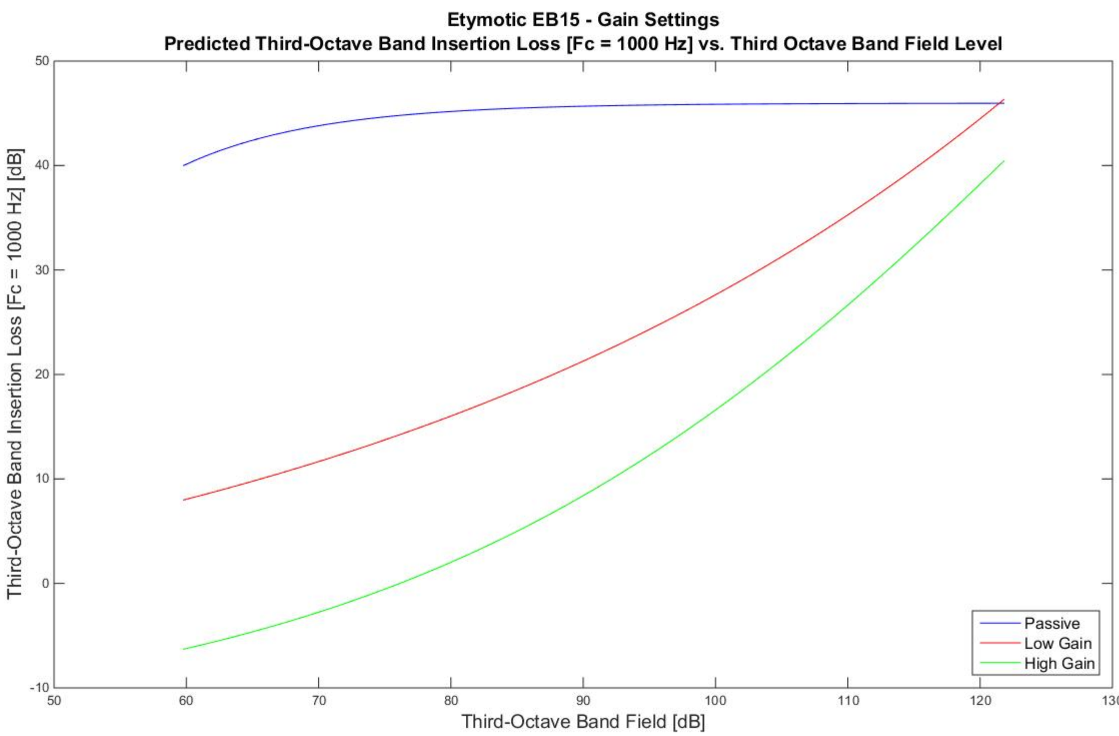

Figure 43. EB15 insertion loss variation based on gain settings - 1000 Hz.

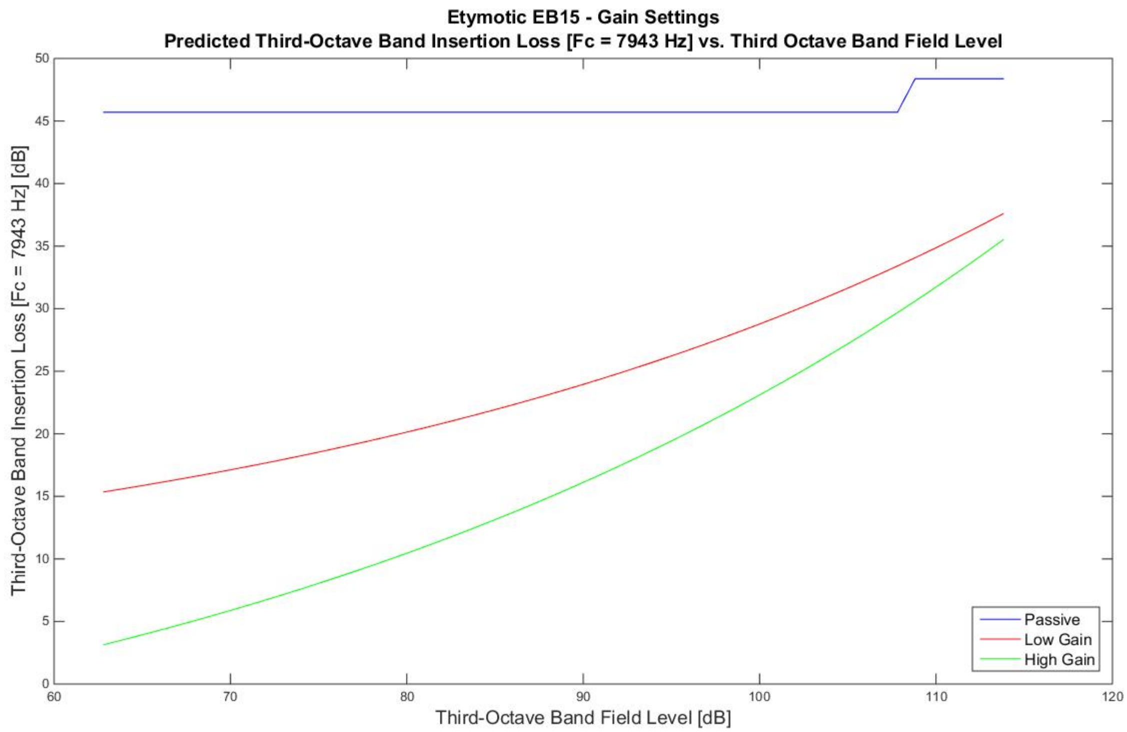

Figure 44. EB15 insertion loss variation based on gain settings - 7943 Hz.

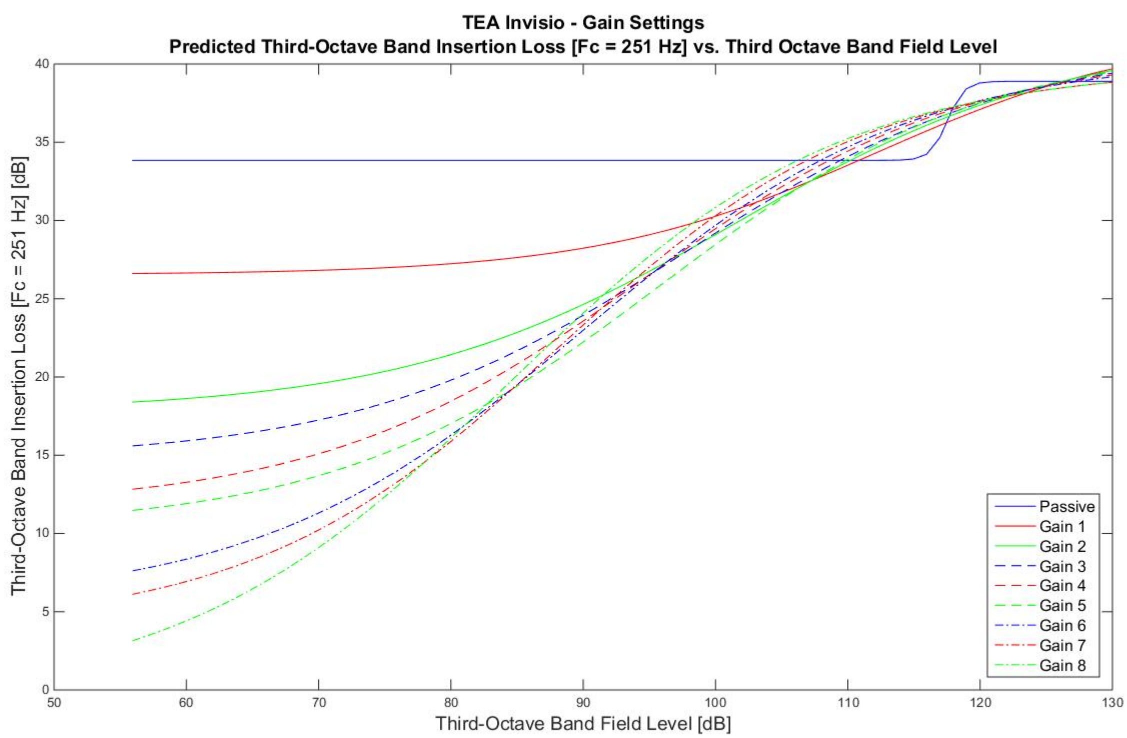

Figure 45. Invisio® insertion loss variation based on gain settings - 251 Hz.

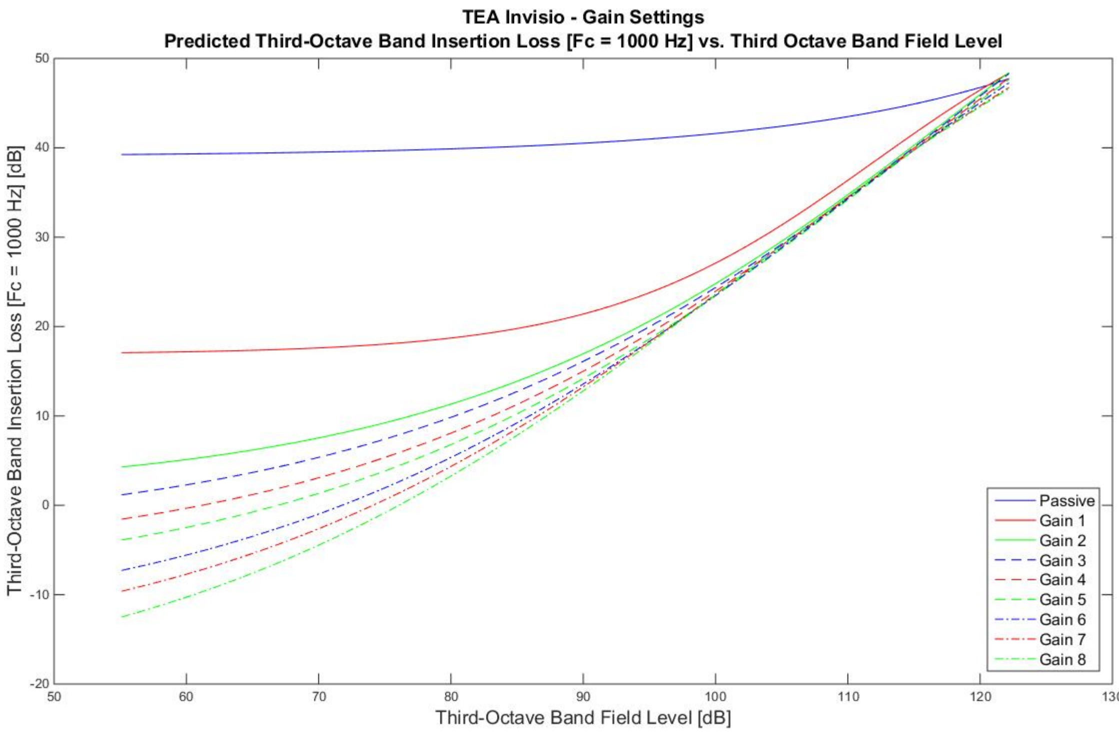

Figure 46. Invisio® insertion loss variation based on gain settings - 1000 Hz.

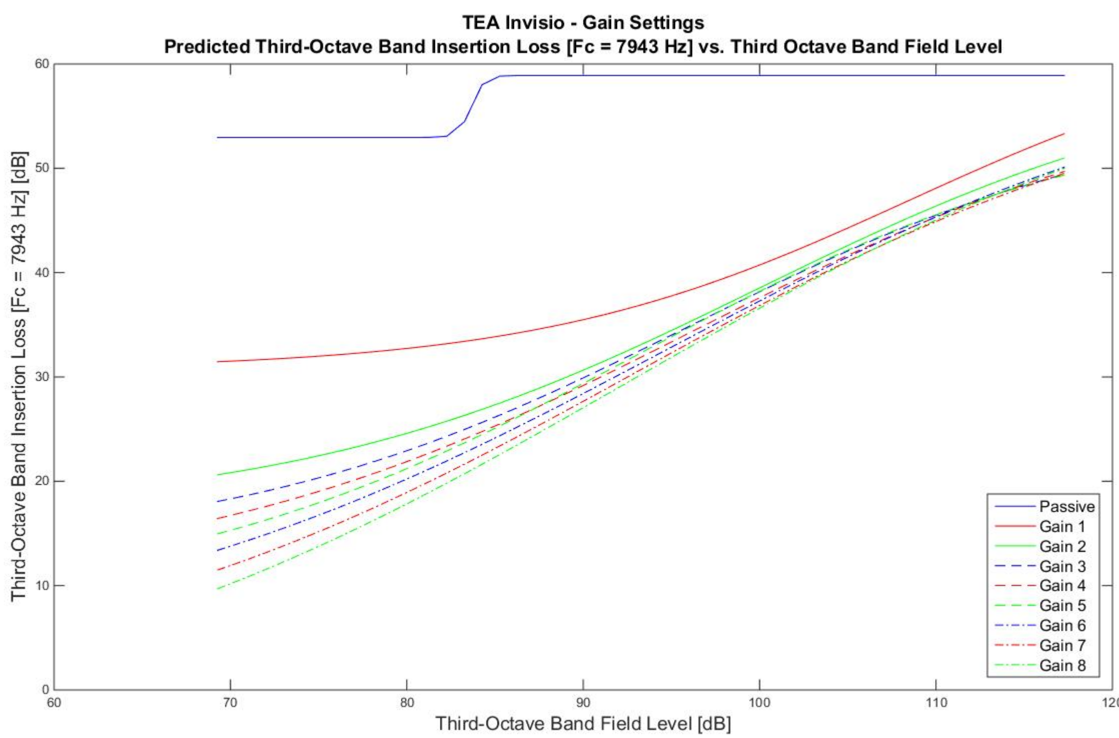

Figure 47. Invisio® insertion loss variation based on gain settings - 7493 Hz.

Given these results, it seems clear that any predictive tool or model of the protective capacity of a nonlinear hearing protector must account for the variations in insertion loss with respect to incident SPL. Furthermore, it seems clear that this must be accounted for regardless of the type of noise exposure. The question remains how to use this data for such a tool. Such a question is exacerbated by the uncertainties in comparing data from ATFs to data from human subjects (such as REAT data), along with the effects of bone and tissue conduction.

ANSI S12.42-2010 proposes a technique for ANR systems that can be modified to serve as a hypothetical method to account for variable insertion loss in estimating the protective capacity of HPDs. For a passive nonlinear protector, this method can be summarized as:

$$A_{total} = REAT + \left[IL_{var}(SPL_{incident}) - IL_{minimum}\right]$$

where A_{total} is the total attenuation in a given band, $REAT$ is the real ear attenuation at threshold in a given band, $IL_{var}(SPL_{incident})$ is the variable insertion loss calculated as a function of the incident SPL (i.e., from a regression analysis similar to the one presented above) in a given band, and $IL_{minimum}$ is the minimum insertion loss value measured at lower SPLs (or the lower asymptote of a logistic regression of measure data).

For an active protector, this method can be summarized as:

$$A_{total} = REAT + \left[IL_{var}(SPL_{incident}) - IL_{passive}\right]$$

where A_{total} is the total attenuation in a given band, $REAT$ is the real ear attenuation at threshold in a given band, $IL_{var}(SPL_{incident})$ is the variable insertion loss calculated as a function of the incident SPL (i.e., from a regression analysis similar to the one presented above) in a given band, and $IL_{passive}$ is the passive insertion loss in a given band. This method accounts for both variable insertion loss and the differences between REAT and ATF data. The total attenuation would be calculated for all the required frequency bands, resulting in a level dependent attenuation which could then be used to formulate a lumped parameter model (similar to that of Kalb) or used along with other damage risk criteria to estimate effective noise exposure. It goes without saying, however, that this method is untested and would require verification prior to implementation.

Conclusions and recommendations

The purpose of this study was to examine nonlinearity in the insertion loss of hearing protection devices. To that end, this paper detailed the collection of a set of insertion loss measurements conducted using an ATF in continuous noise from 55 to 130 dB and impulsive noise from 110 to 170 dB peak SPL. The resulting data was examined in terms of third-octave band insertion loss to determine if predictive models for the protective capacity of HPDs need to consider variable insertion loss. In the case of passive devices with no nonlinear design features, such as the EAR Classic™, the data collected indicate that nonlinearity does not need to be considered. However, intentionally nonlinear devices, such as the Combat Arms Earplug™, require consideration of nonlinearity when predicting the protective capacity of HPDs

Additionally, a regression analysis indicates that the insertion loss values in some frequency bands correlate well with measurements of the incident noise. This means that as the sound level increases, the insertion loss, or protection, provided by active protectors also increases. Based on such a regression, it is straightforward to envision a technique using REAT values for a protector as a baseline, while the variability could be described using the results of ATF testing, resulting in a level dependent transfer function to predict protective capacity of a hearing protector. As stated previously, this method can be summarized for an active protector as:

$$A_{total} = REAT + \left[IL_{var}(SPL_{incident}) - IL_{passive}\right]$$

where A_{total} is the total attenuation in a given band, $REAT$ is the real ear attenuation at threshold in a given band, $IL_{var}(SPL_{incident})$ is the variable insertion loss calculated as a function of the incident SPL (i.e., from a regression analysis similar to the one presented above) in a given band, and $IL_{passive}$ is the passive insertion loss in a given band.

Active noise reduction technologies (ANR) were not examined as a part of this study, nor were double hearing protection conditions (wearing both plugs and earmuffs). It is recommended to conduct similar research on both active noise reduction and double protection. Further, the data collected in this study have not been subjected to a rigorous statistical analysis, the results of which could aid in determining data collection requirements for future work such as a study involving ANR or double protection.

If a regression technique is to be used to predict the protective capacity of HPDs, it is worthwhile to collect data that compares the predicted performance to actual measured performance. Doing so would require additional data collection using different noise sources.

One issue during the data collection and analysis for this study was the limits in dynamic range of the measurement systems, specifically the transducers used for the ears of the head form. Testing very low noise conditions resulted in questionable data due to the low signal to noise ratio. Examination of additional techniques, such as using microphones with low self-noise, to improve such measurements is recommended.

At the same time, if variable insertion loss is significant, HPDs should be tested beyond the range of their expected use. In this study, peak SPLs were limited to 170 dB peak, while known

sources of noise can produce levels over 185 dB peak. It is recommended to determine the absolute upper limit for HPD testing and develop methods and transducers to test to those levels.

Finally, hearing and auditory disorders continue to be the most prevalent occupational injuries suffered by military service members so it is important that the attenuation characteristics of HPDs used by the military are fully understood. This study examined the attenuation performance of devices over relatively long time scales, even for impulsive noises. The results of this study may not be applicable in the event of a requirement for a very accurate time-domain model of HPDs.

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Appendix.

Third-octave band insertion loss plots

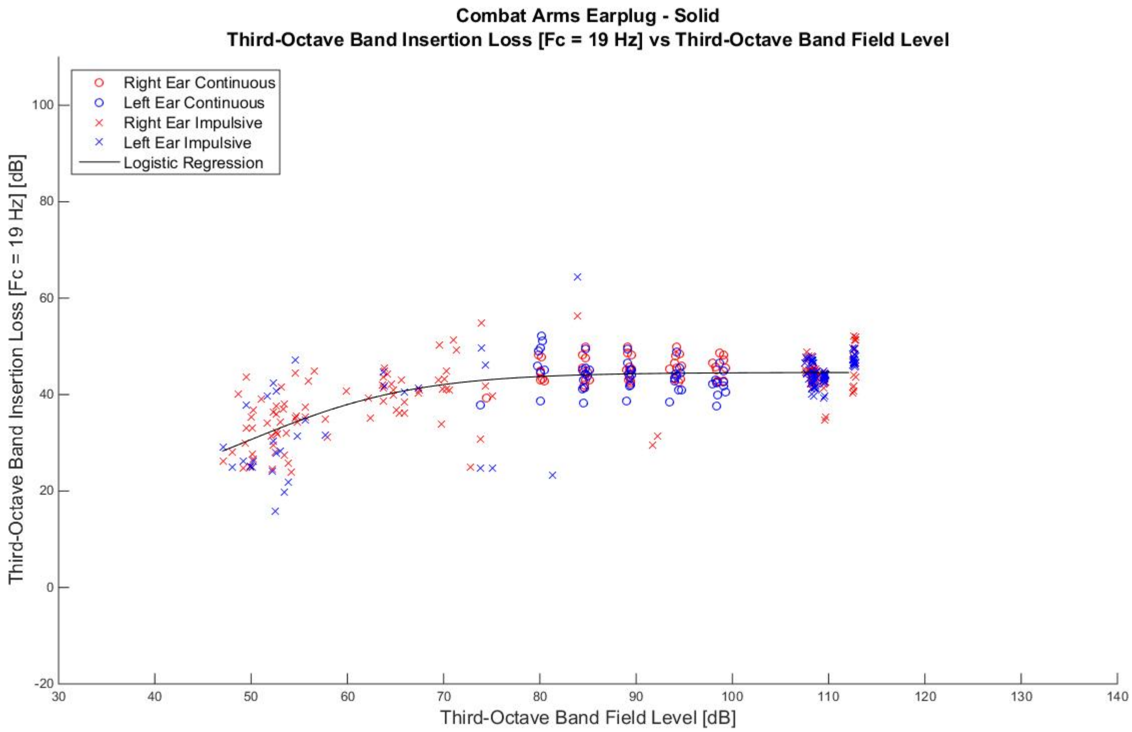

Figure A-1. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

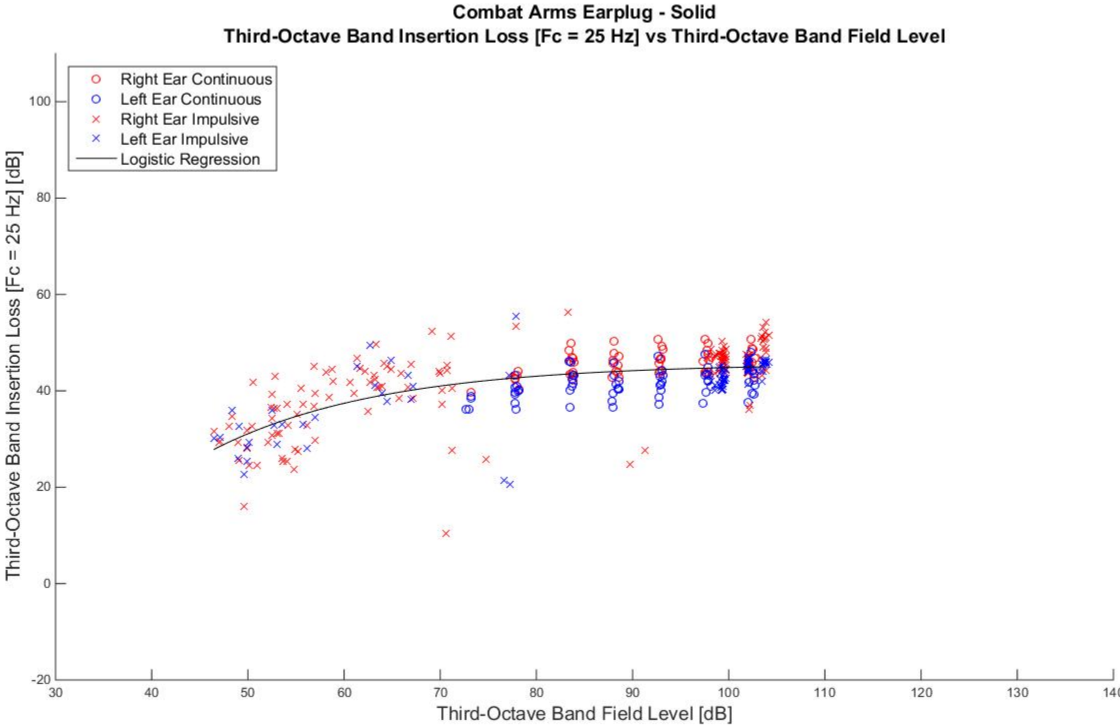

Figure A-2. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

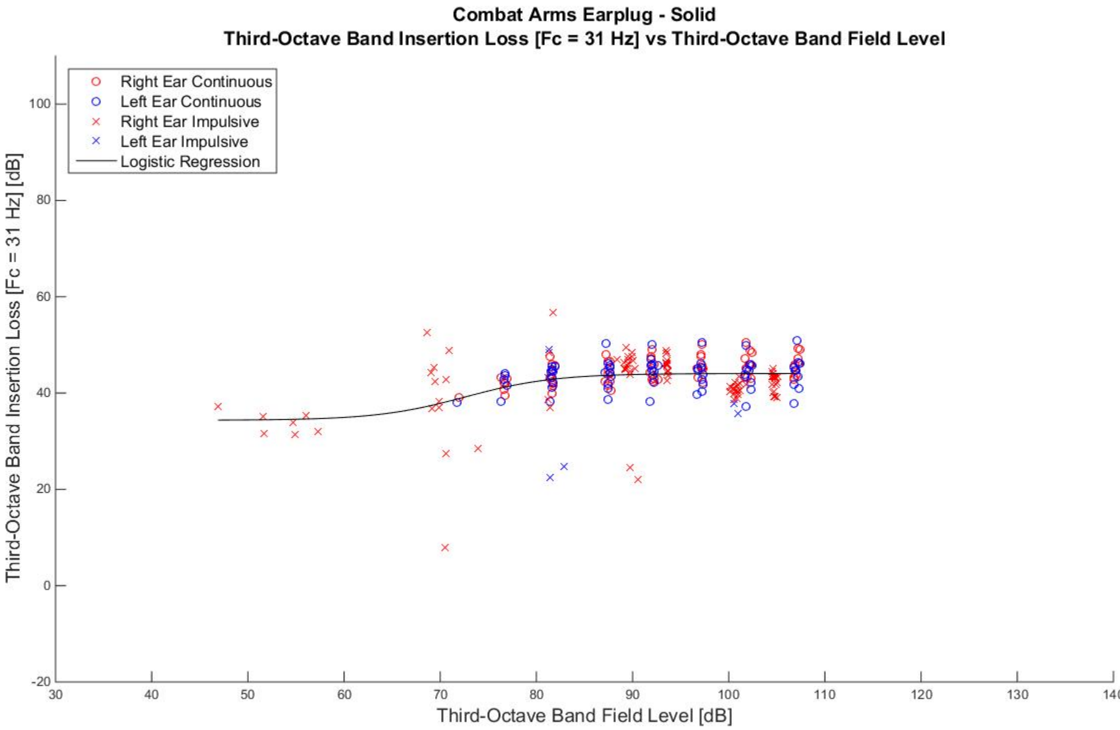

Figure A-3. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

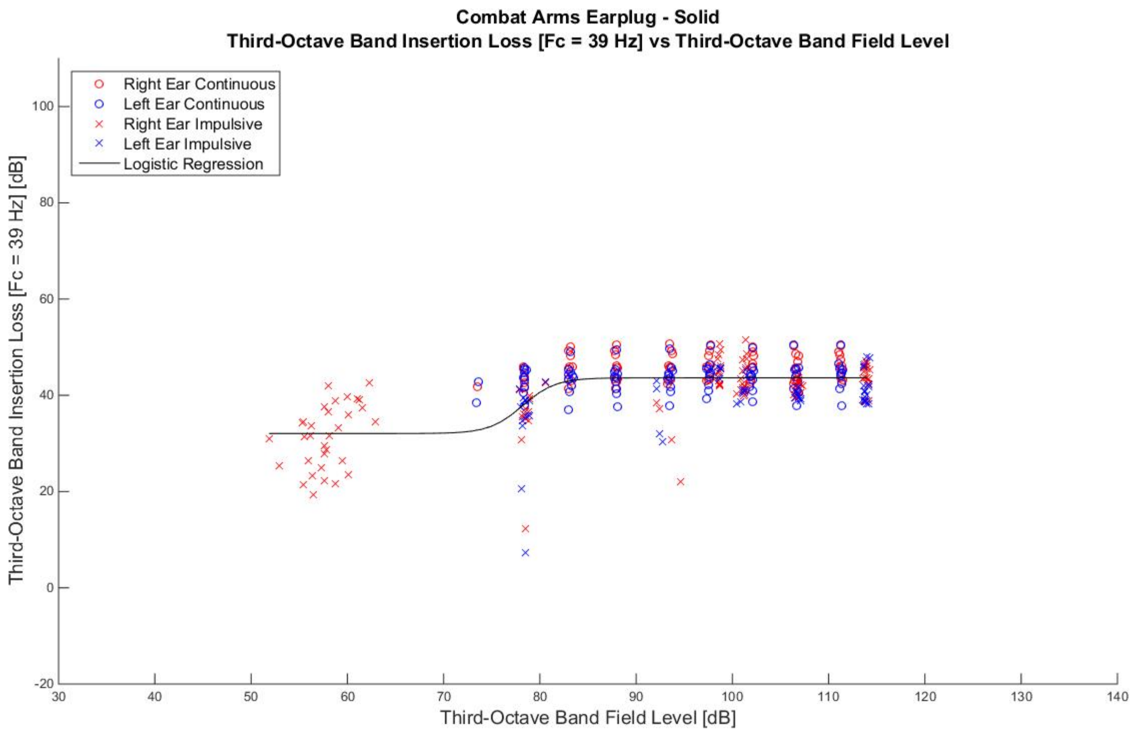

Figure A-4. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

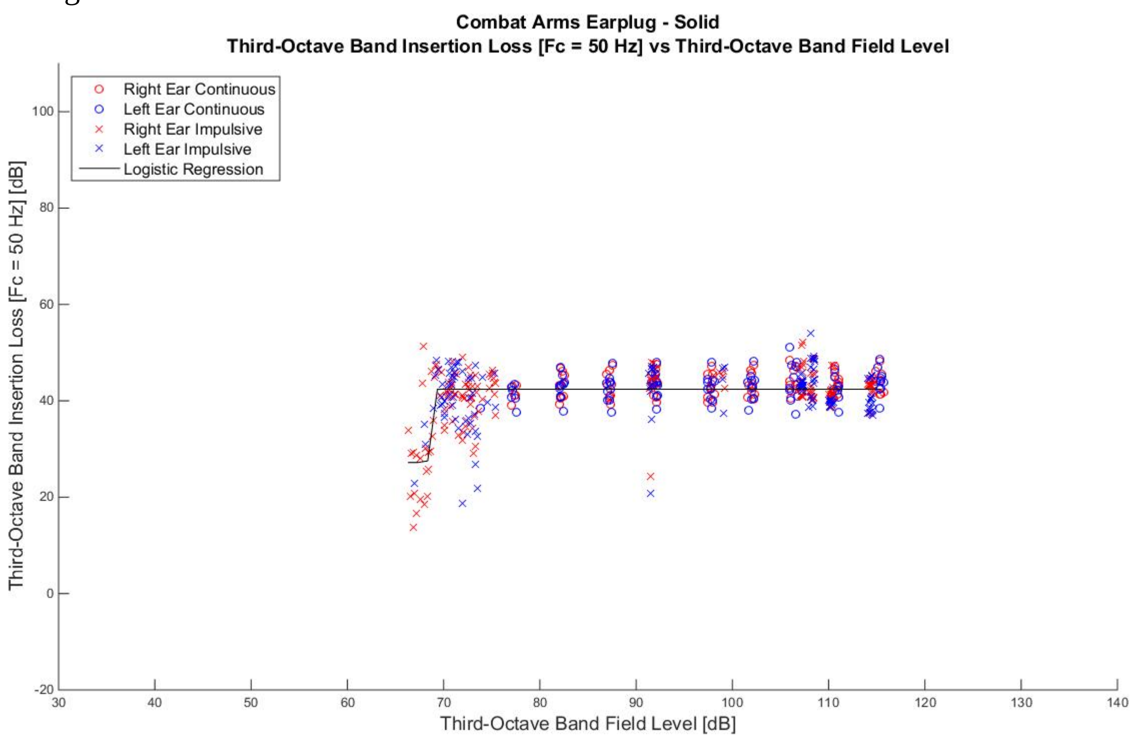

Figure A-5. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

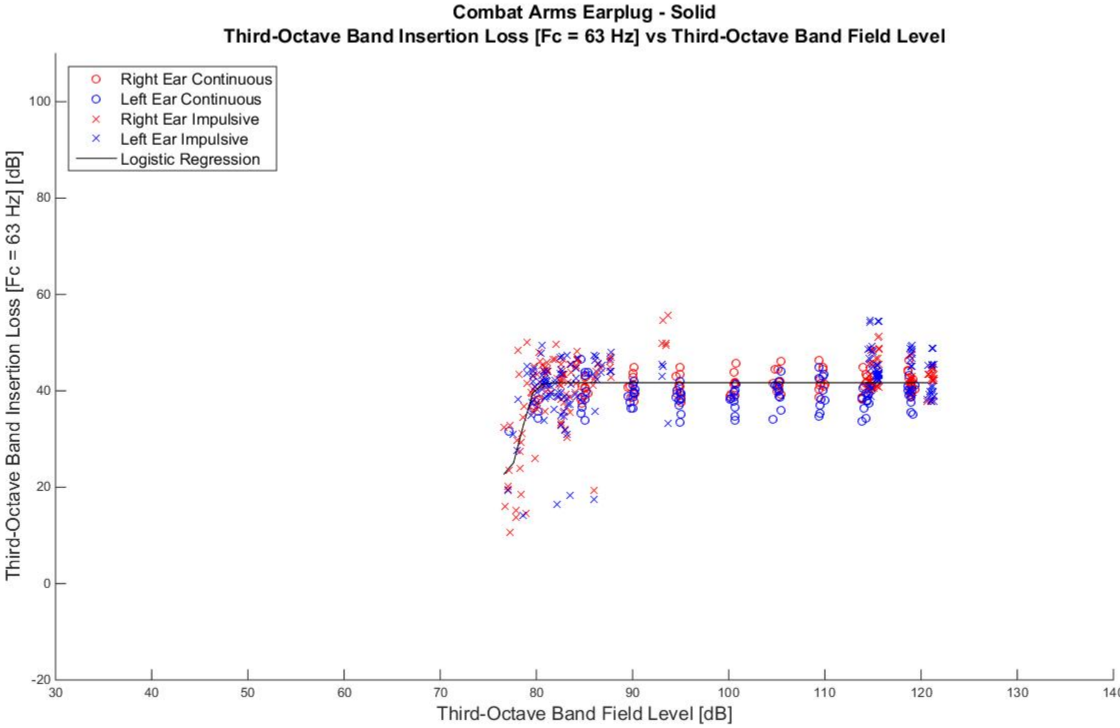

Figure A-6. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

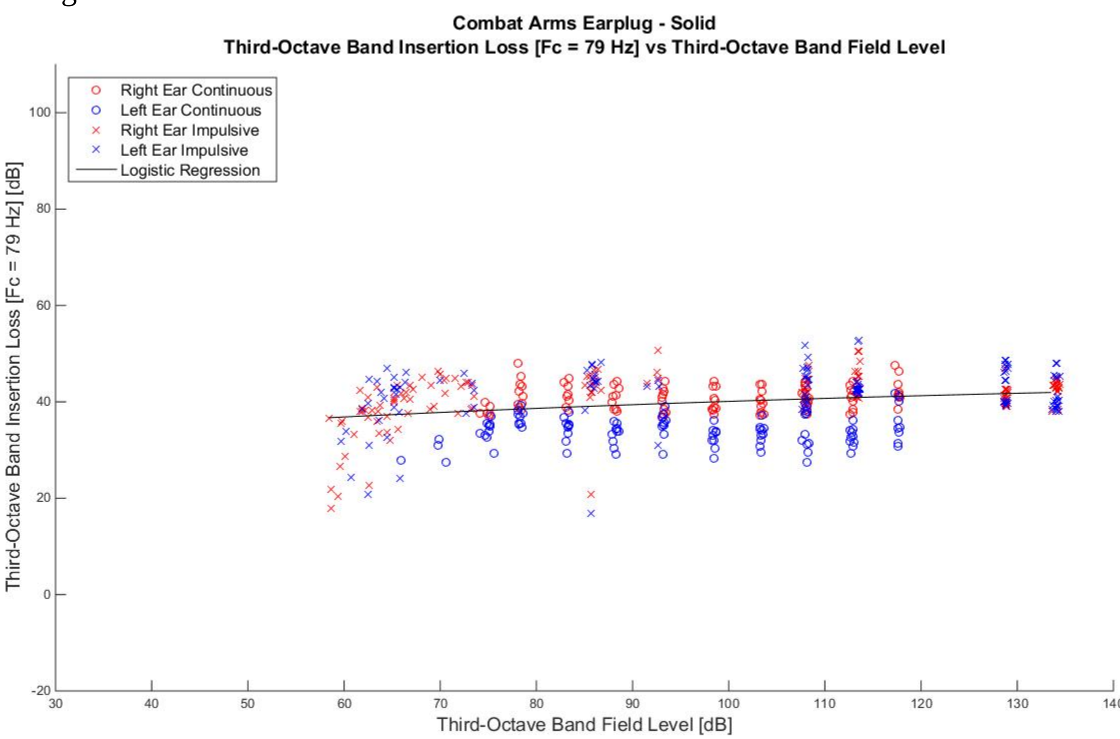

Figure A-7. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

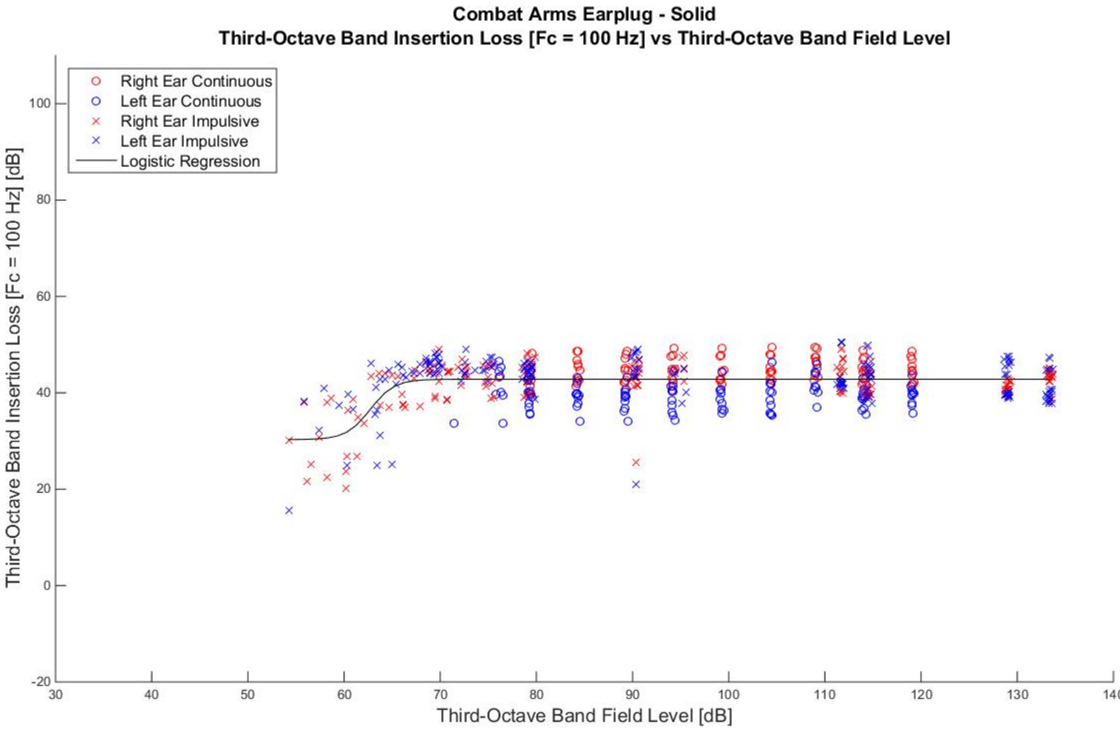

Figure A-8. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

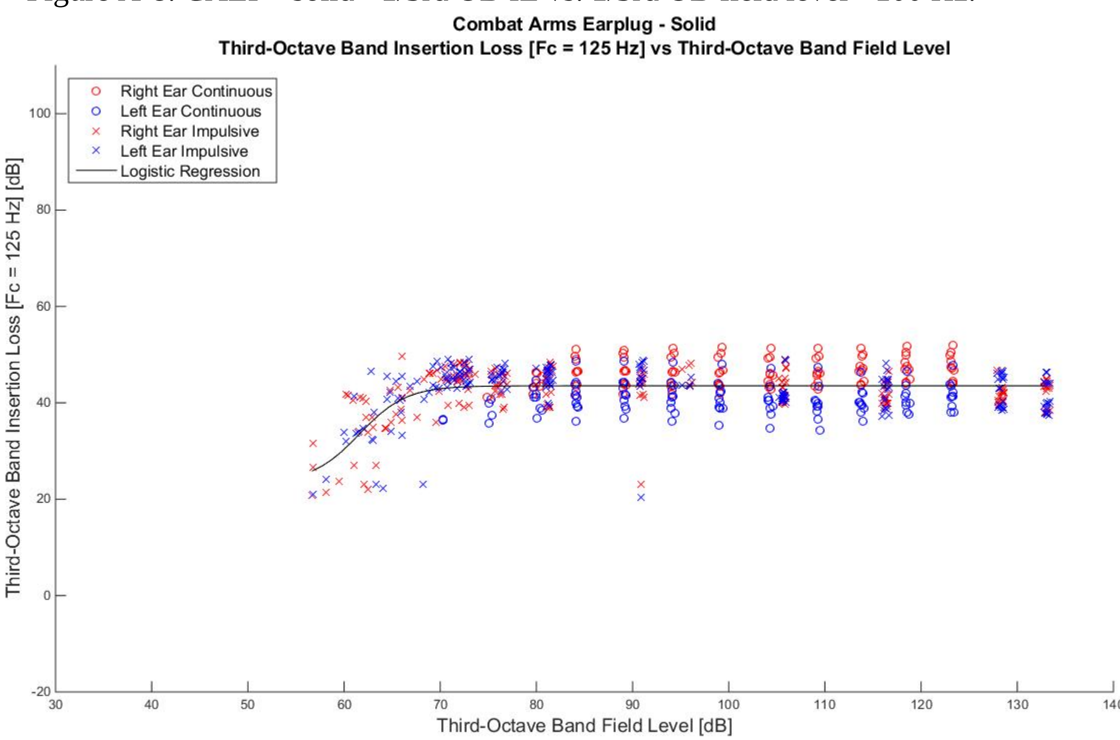

Figure A-9. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

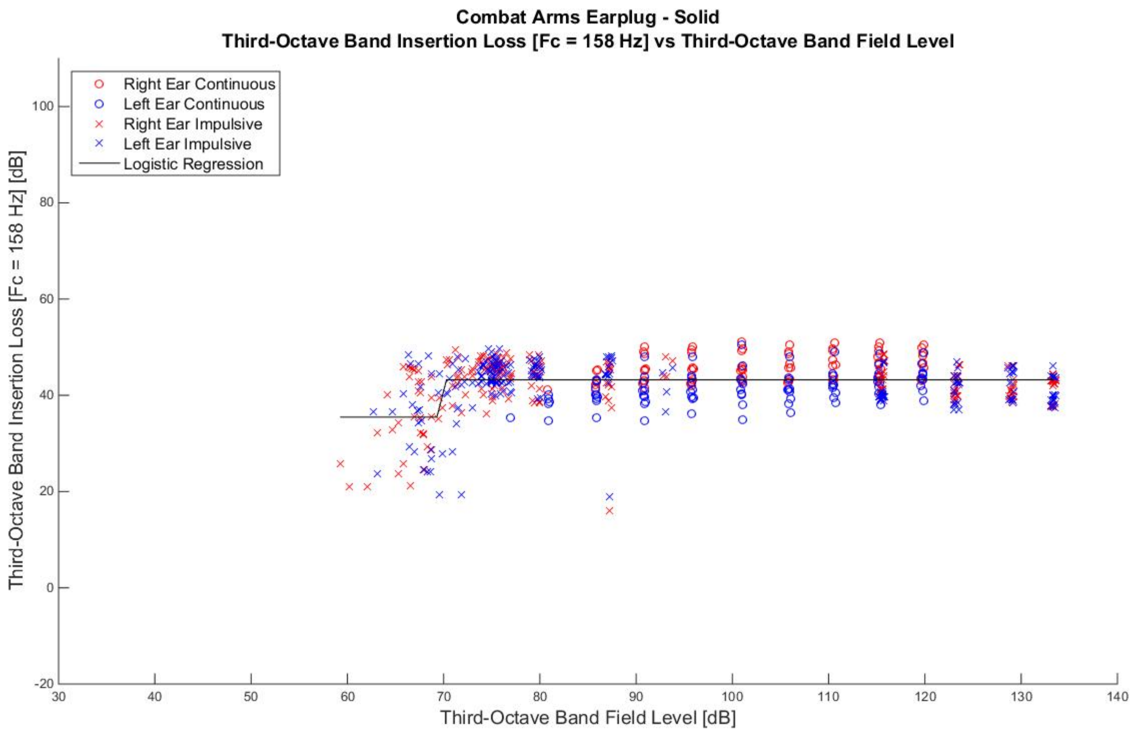

Figure A-10. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

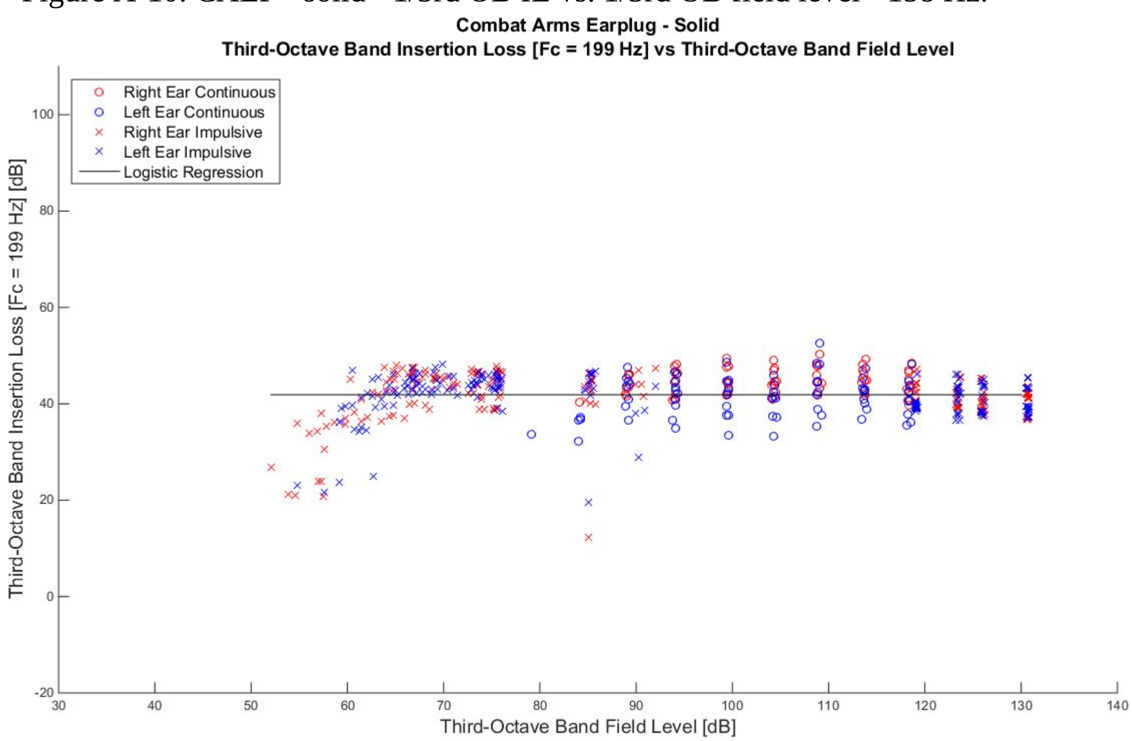

Figure A-11. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

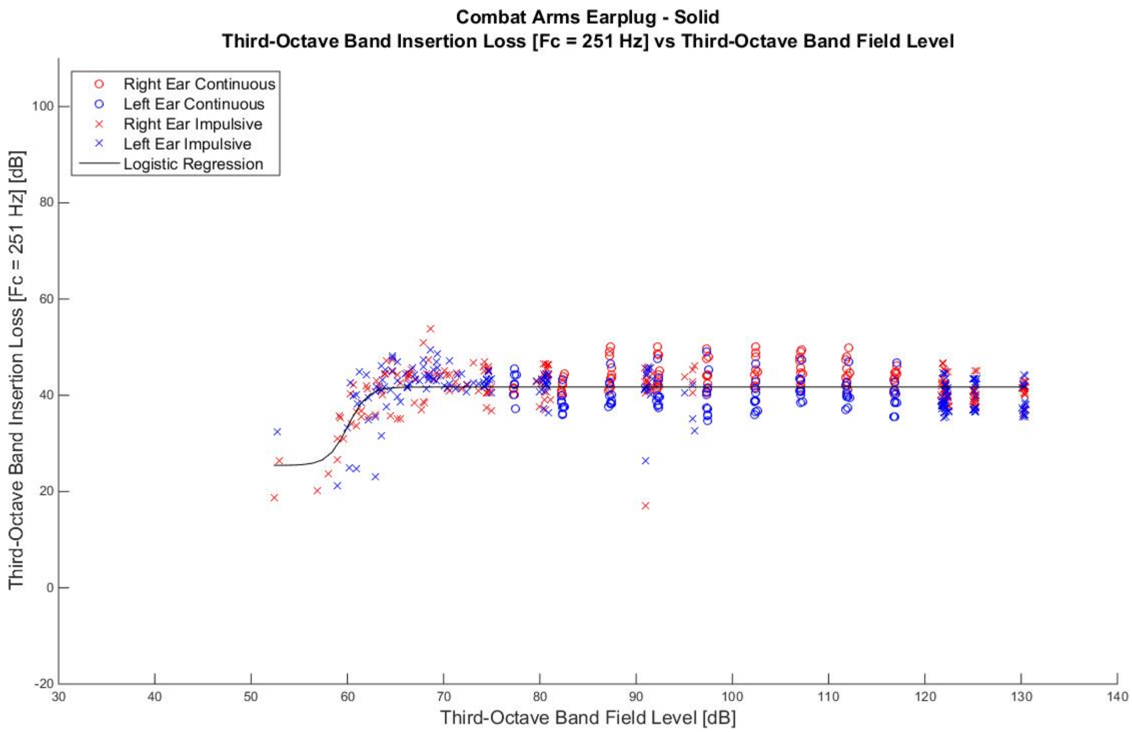

Figure A-12. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

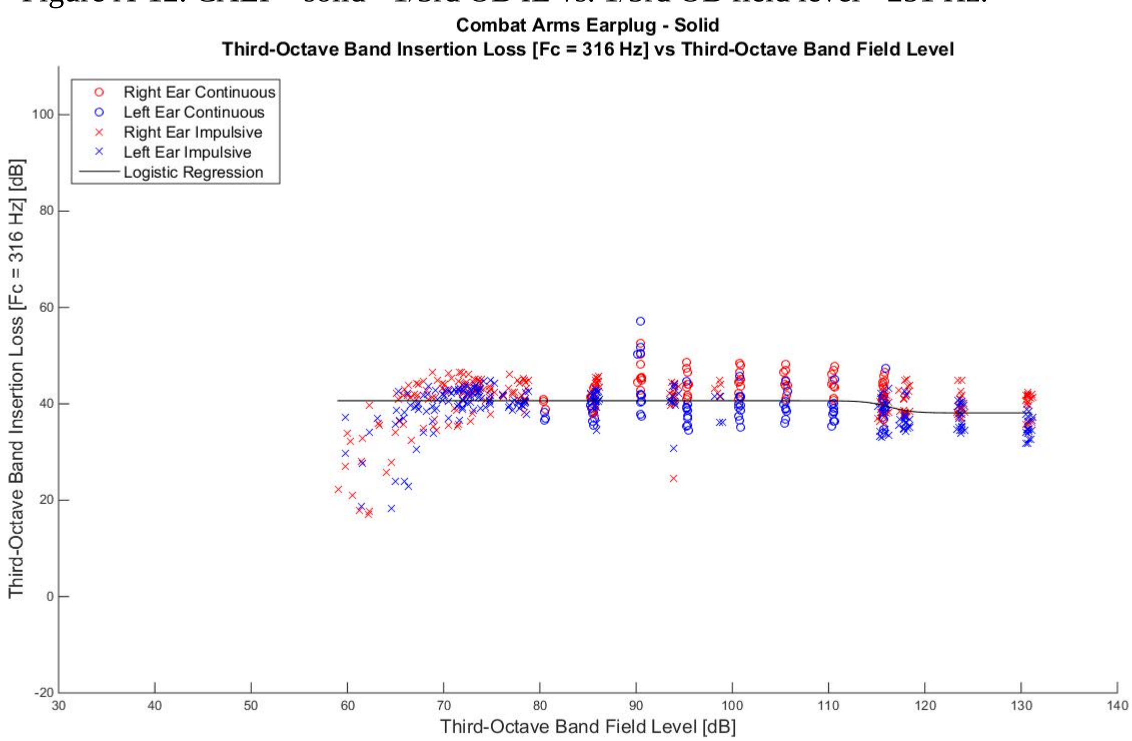

Figure A-13. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

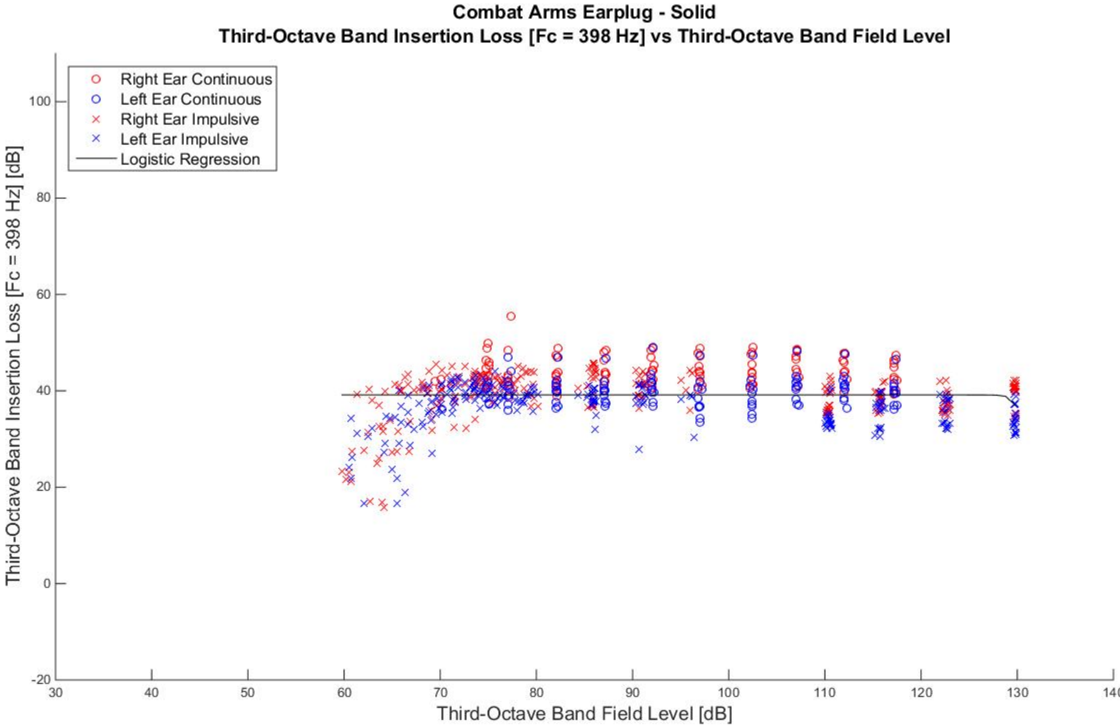

Figure A-14. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

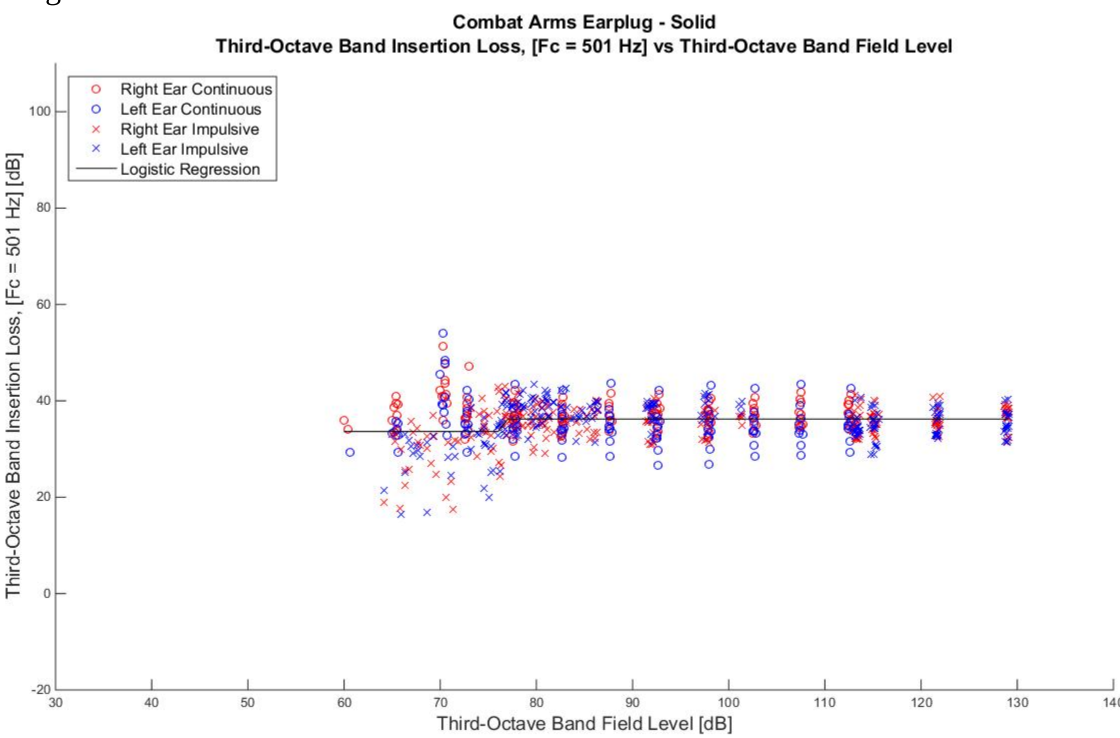

Figure A-15. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

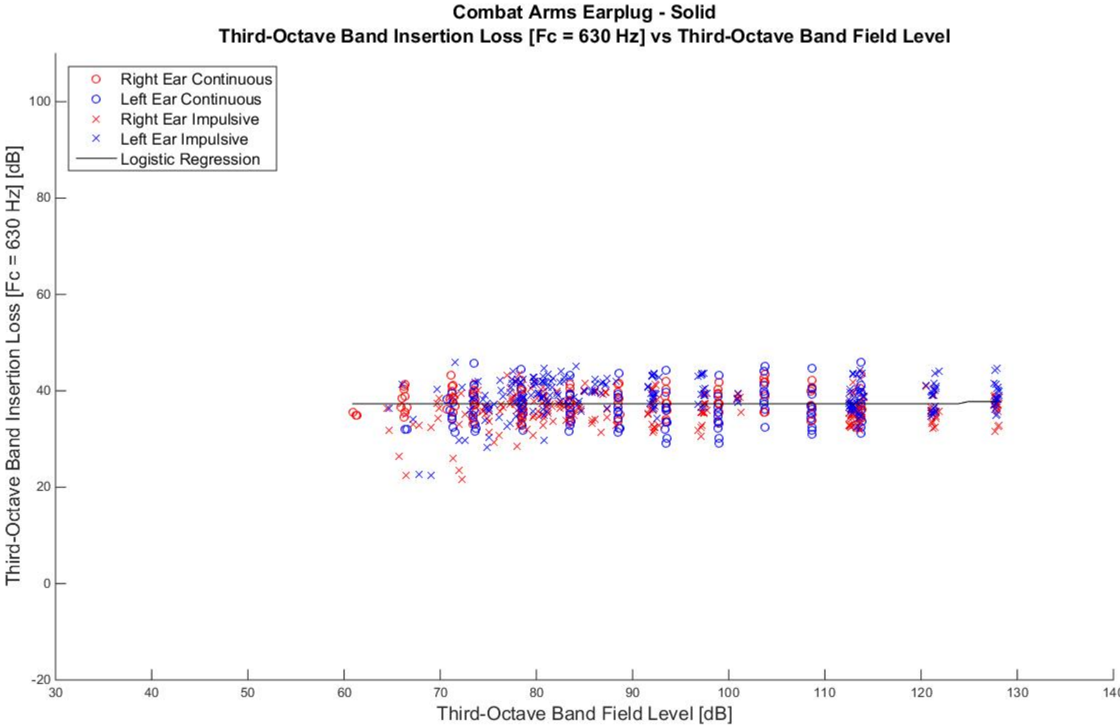

Figure A-16. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

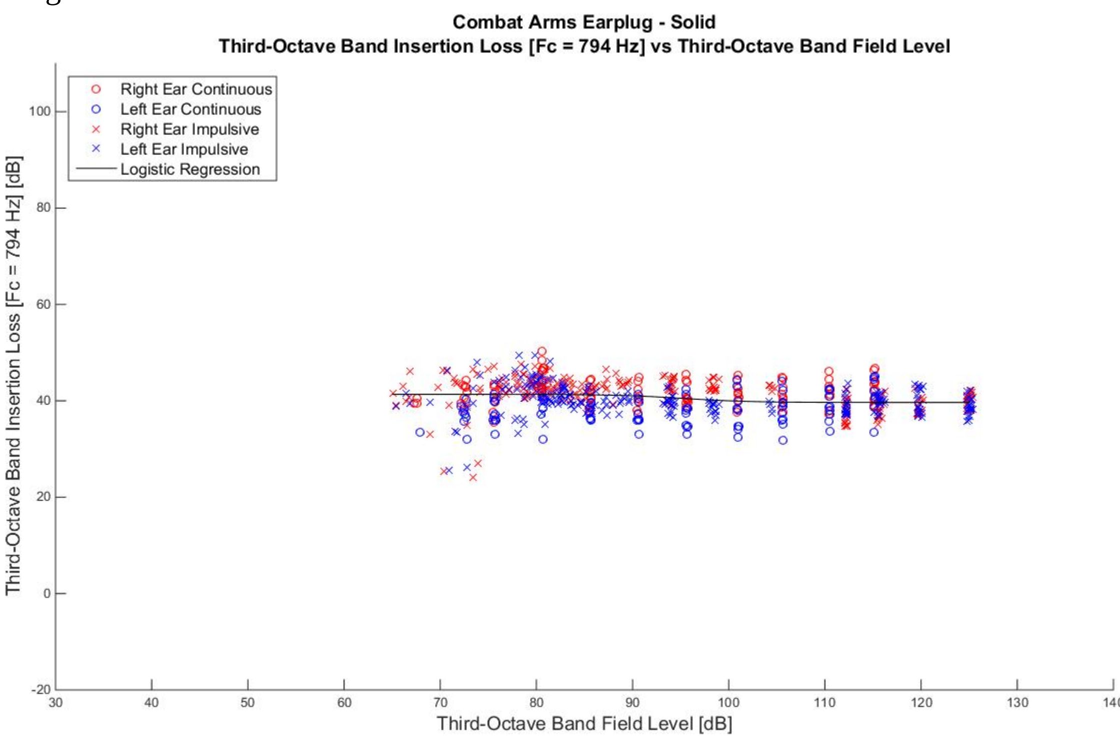

Figure A-17. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

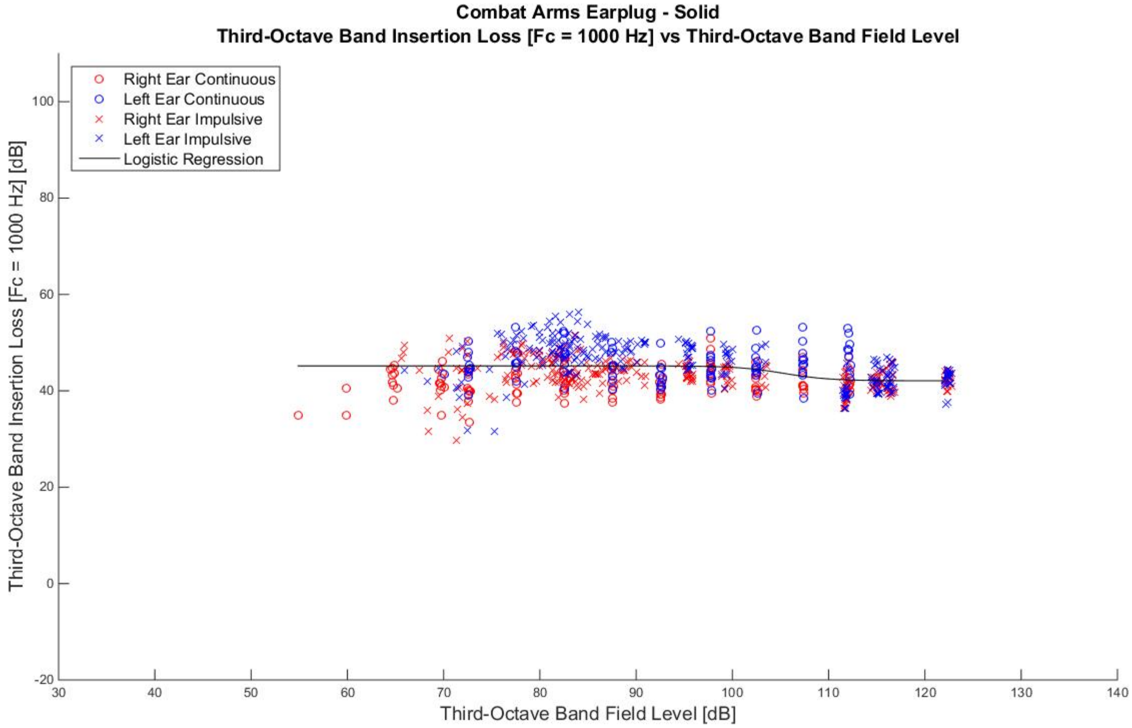

Figure A-18. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

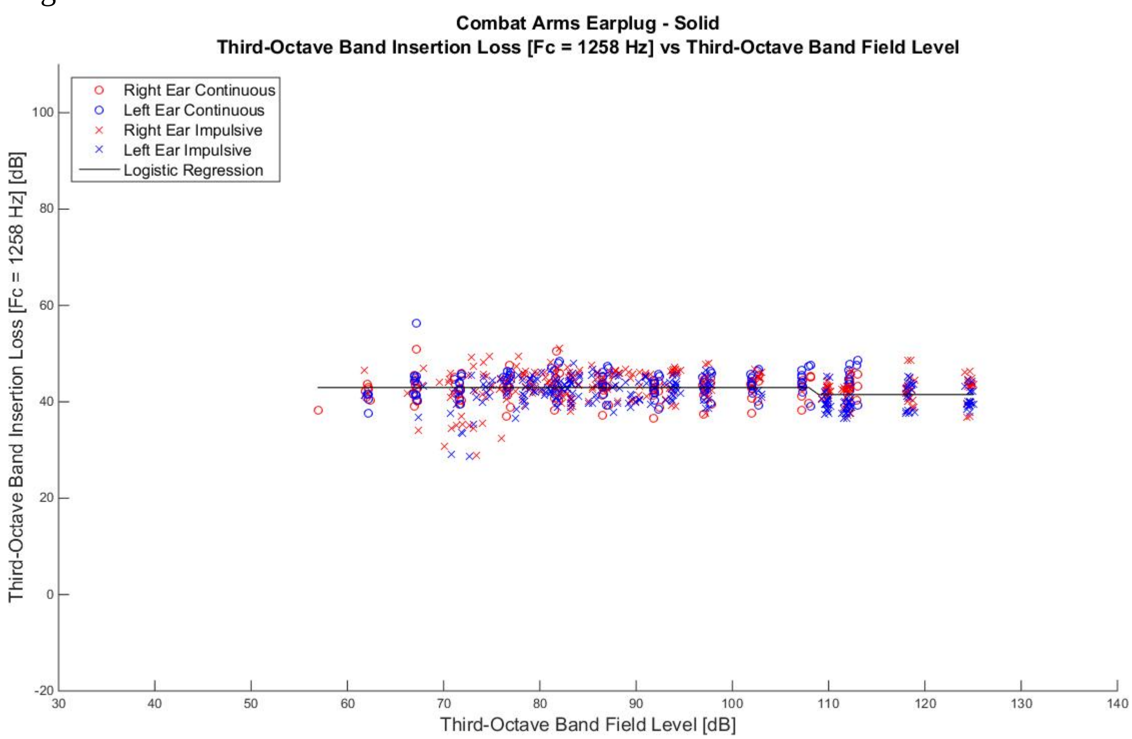

Figure A-19. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

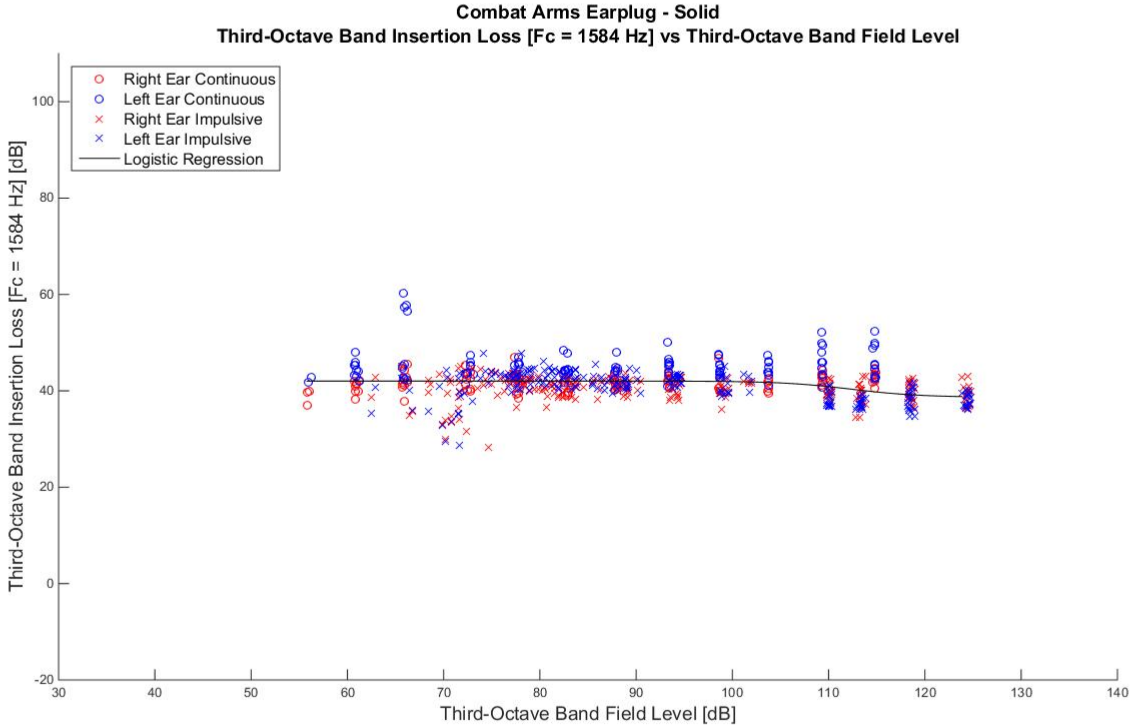

Figure A-20. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

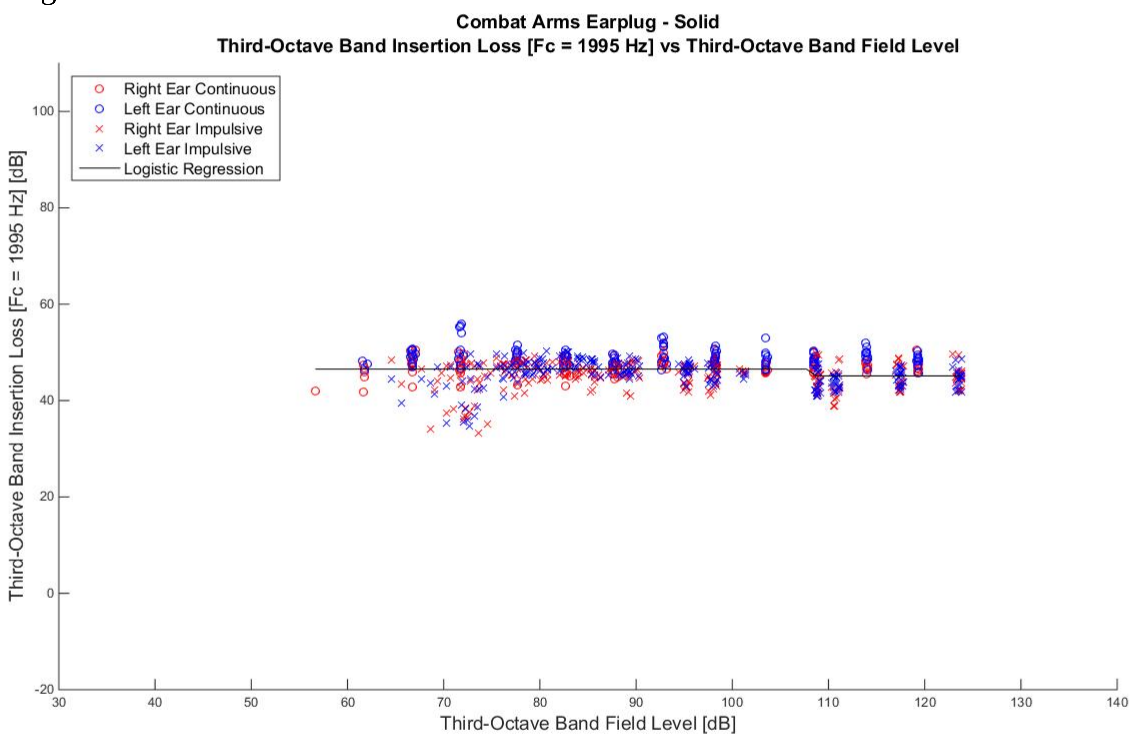

Figure A-21. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

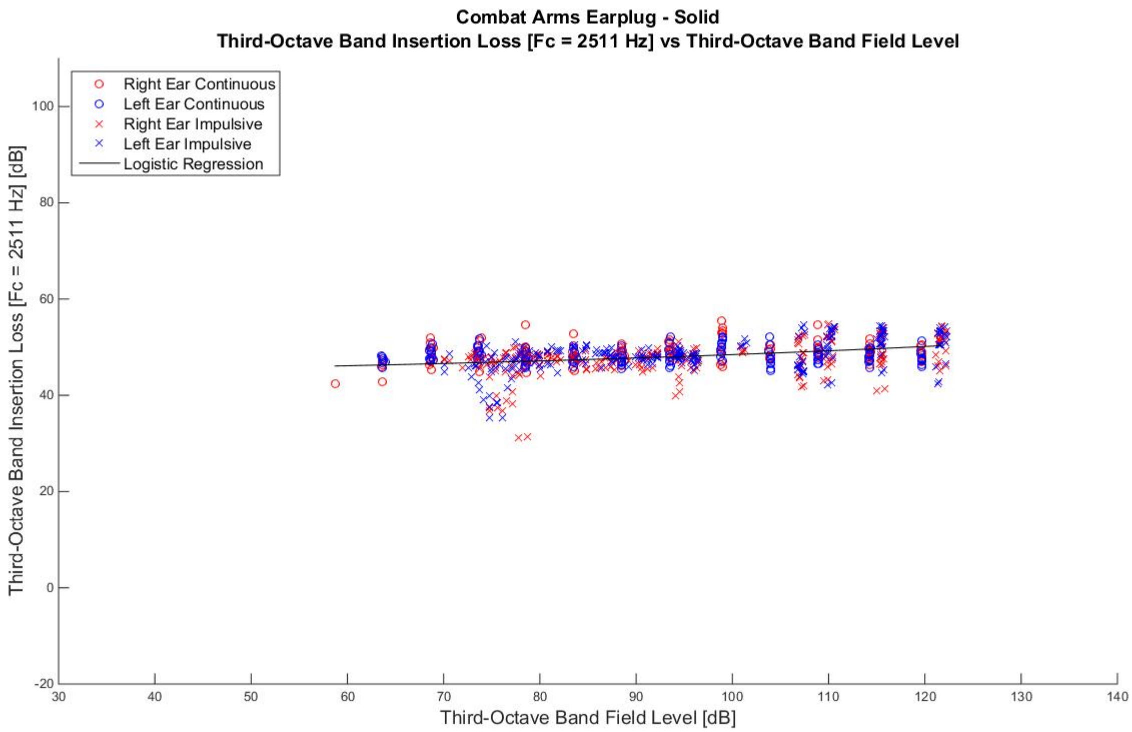

Figure A-22. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

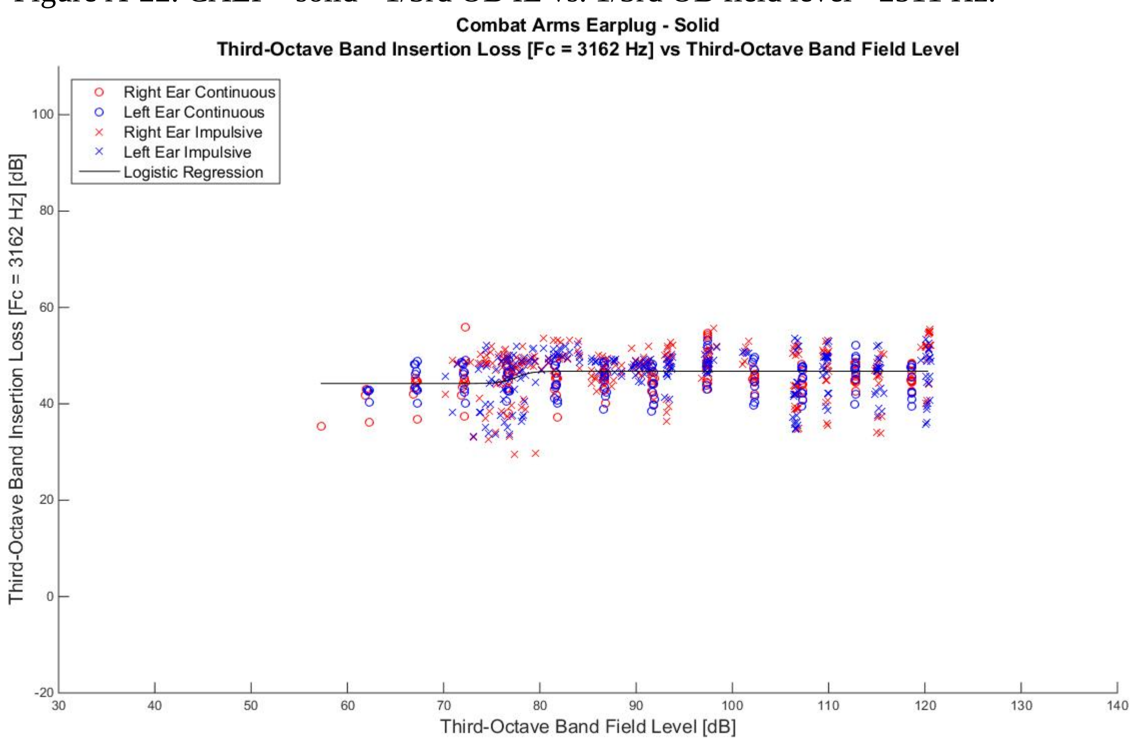

Figure A-23. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

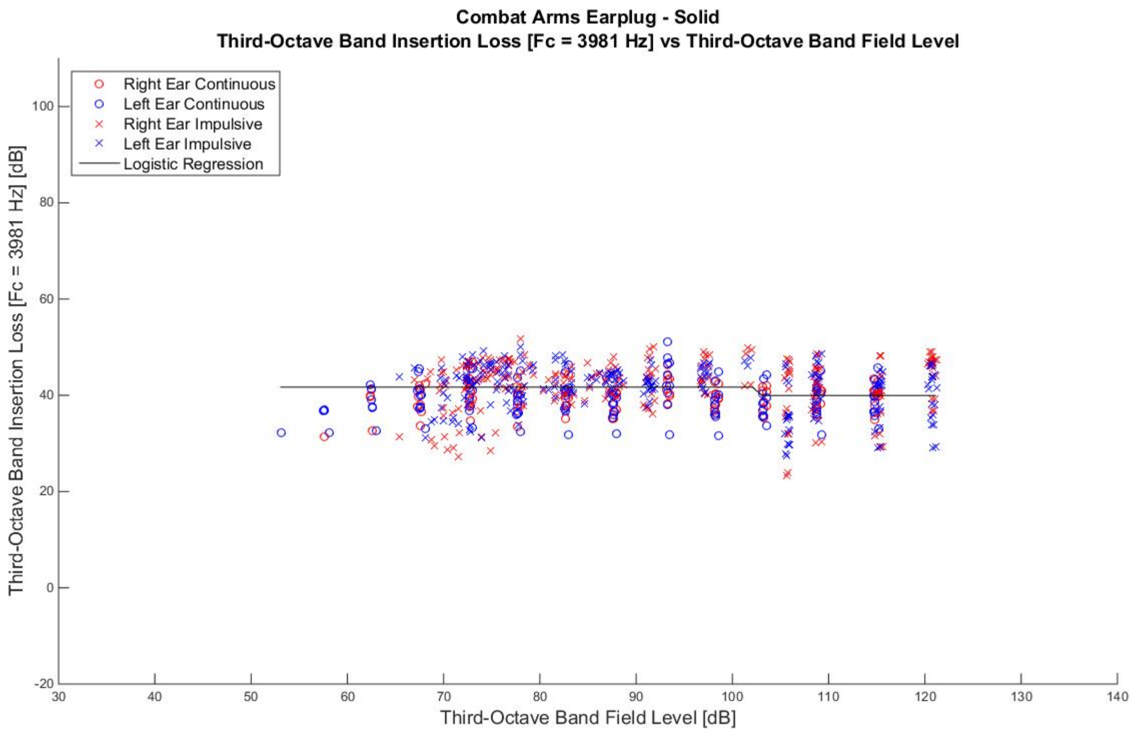

Figure A-24. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

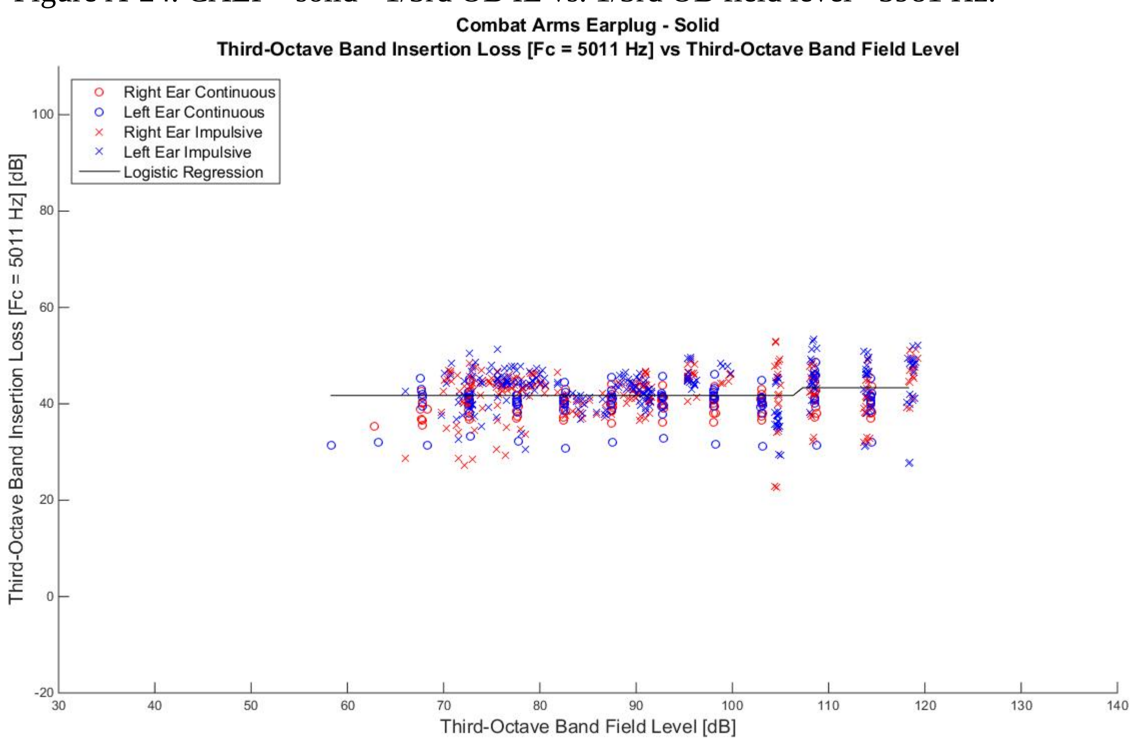

Figure A-25. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

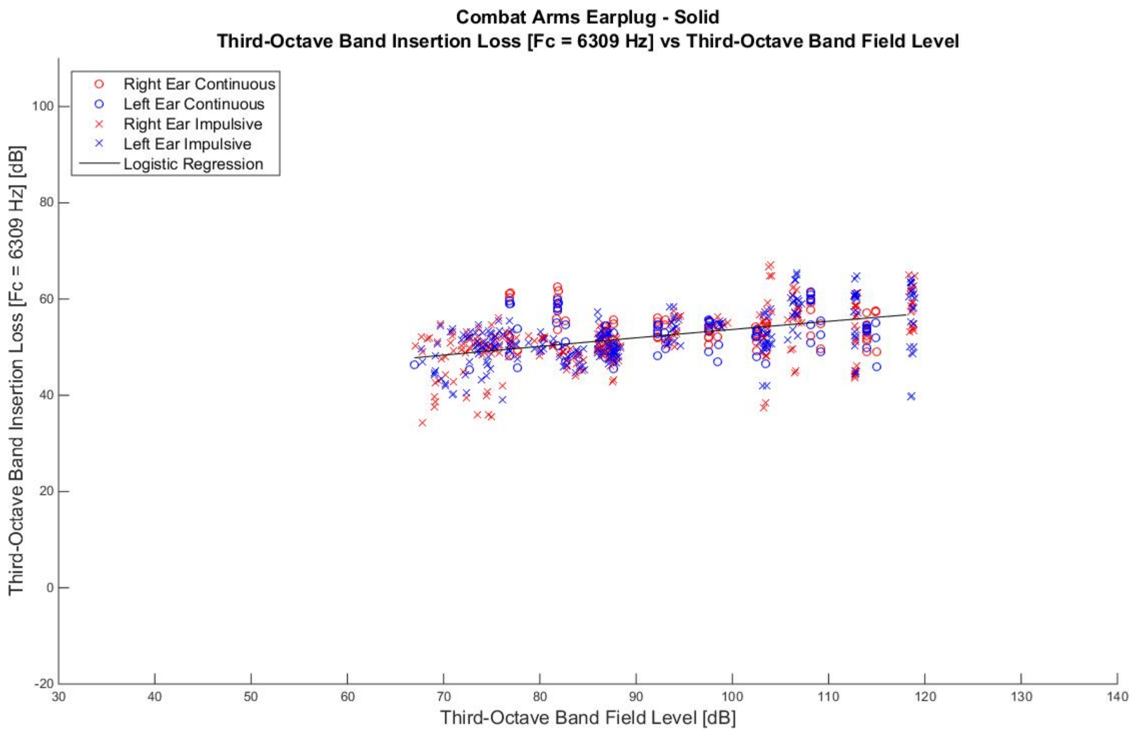

Figure A-26. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

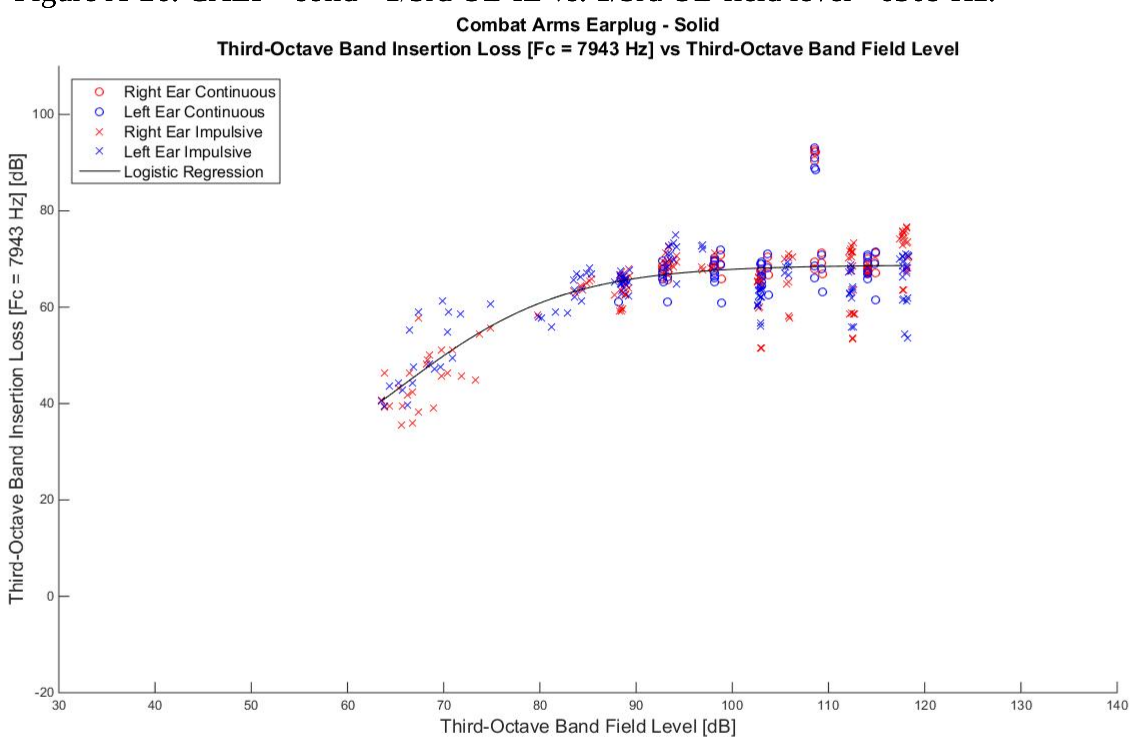

Figure A-27. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

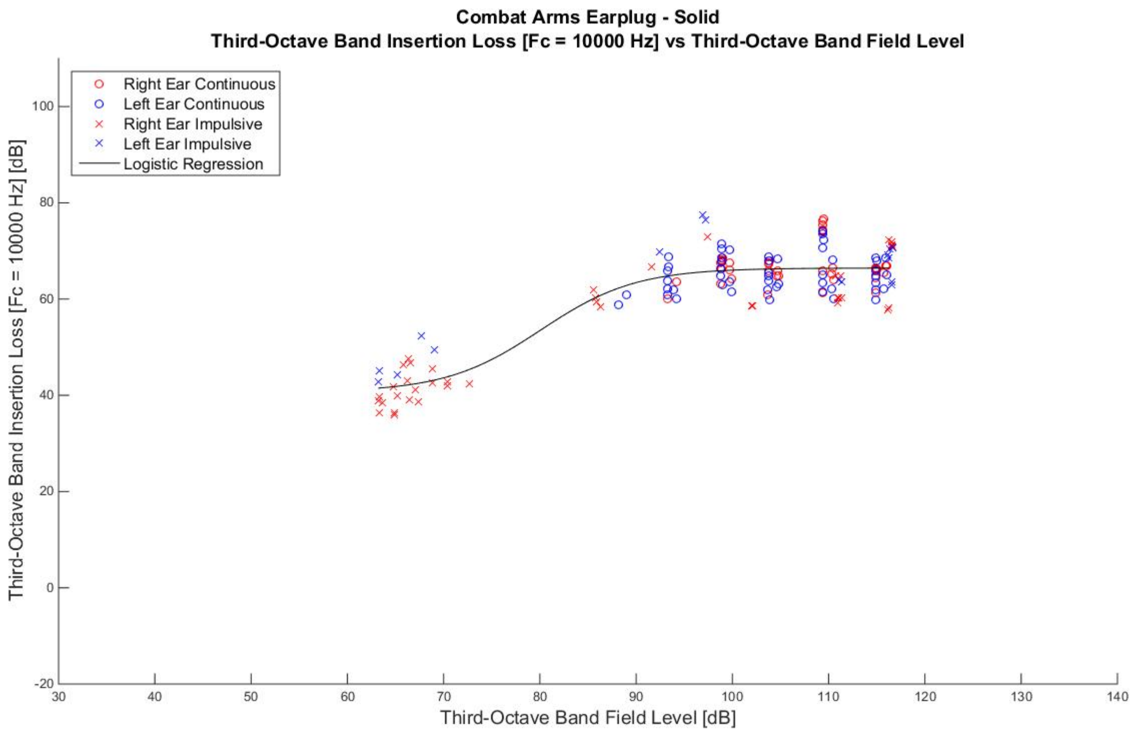

Figure A-28. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

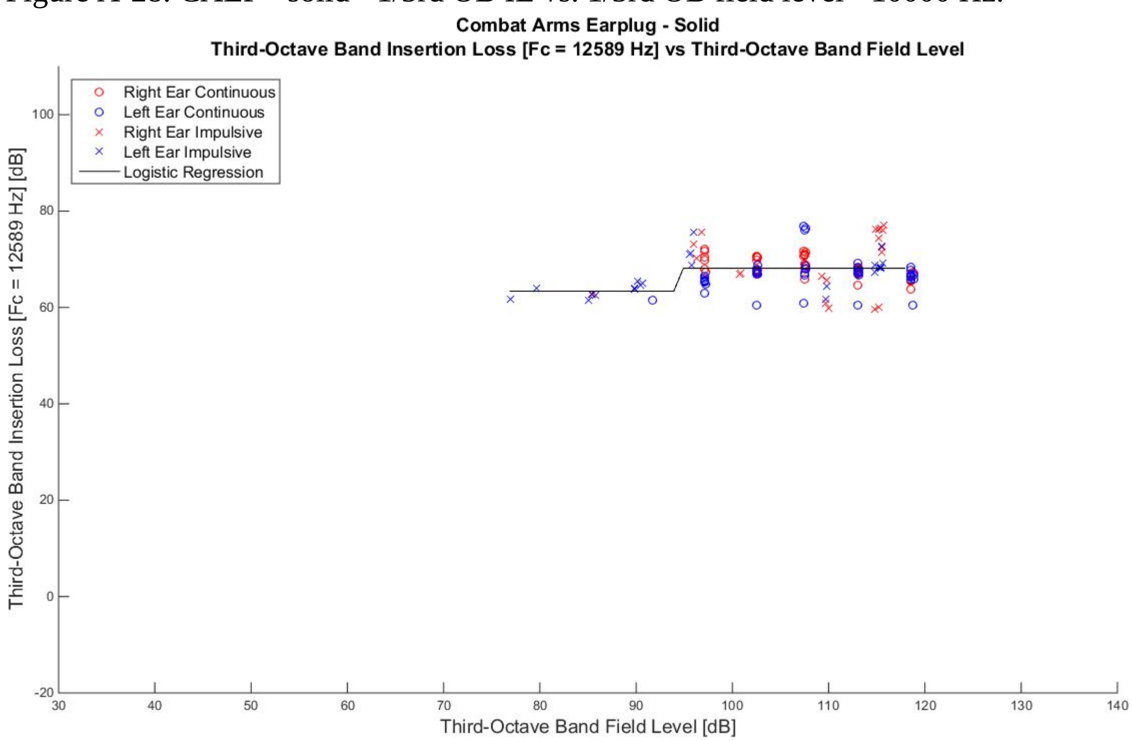

Figure A-29. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

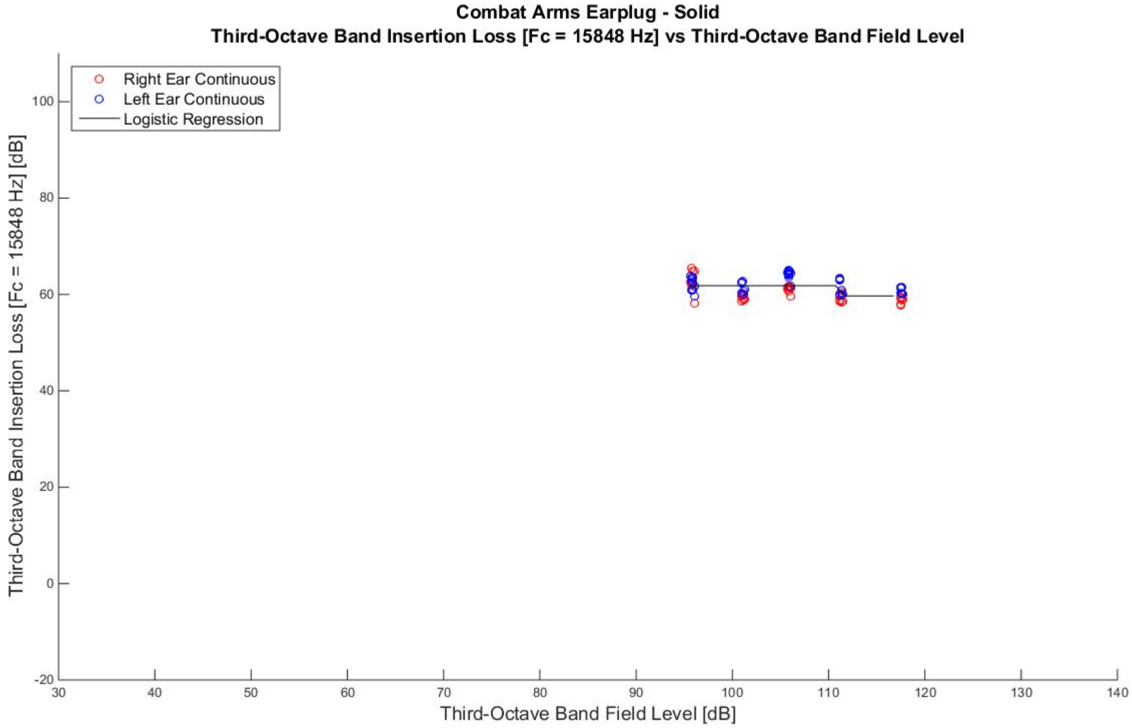

Figure A-30. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

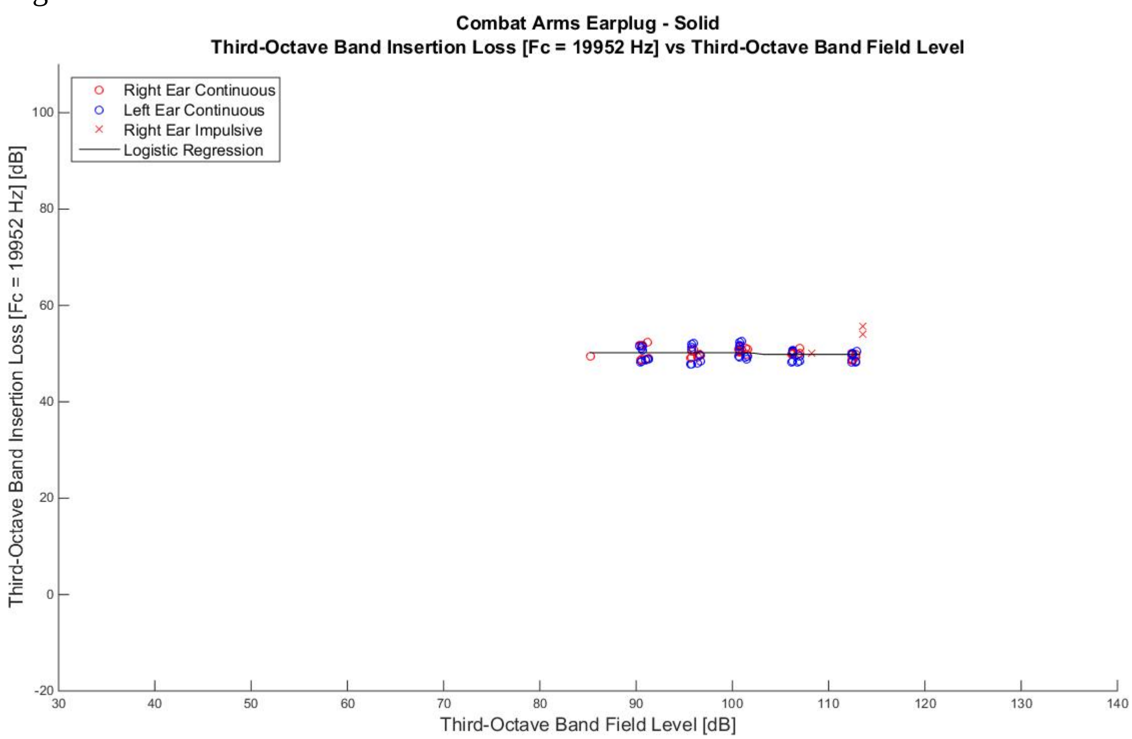

Figure A-31. CAEP - solid - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

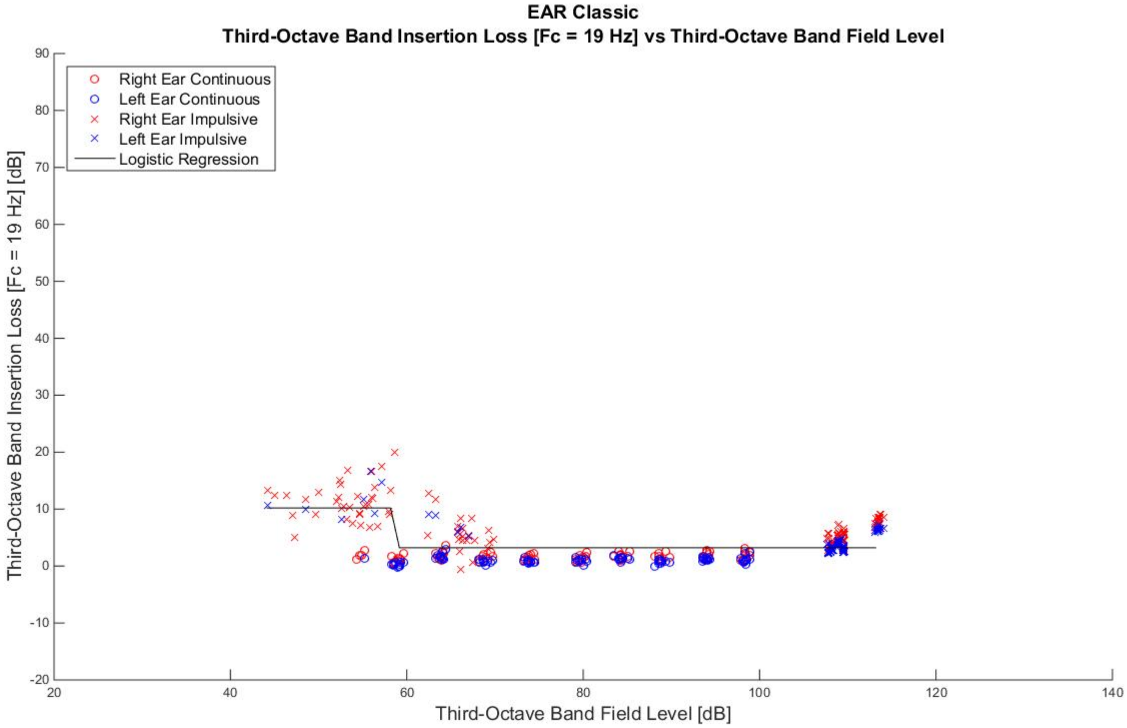

Figure A-32. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

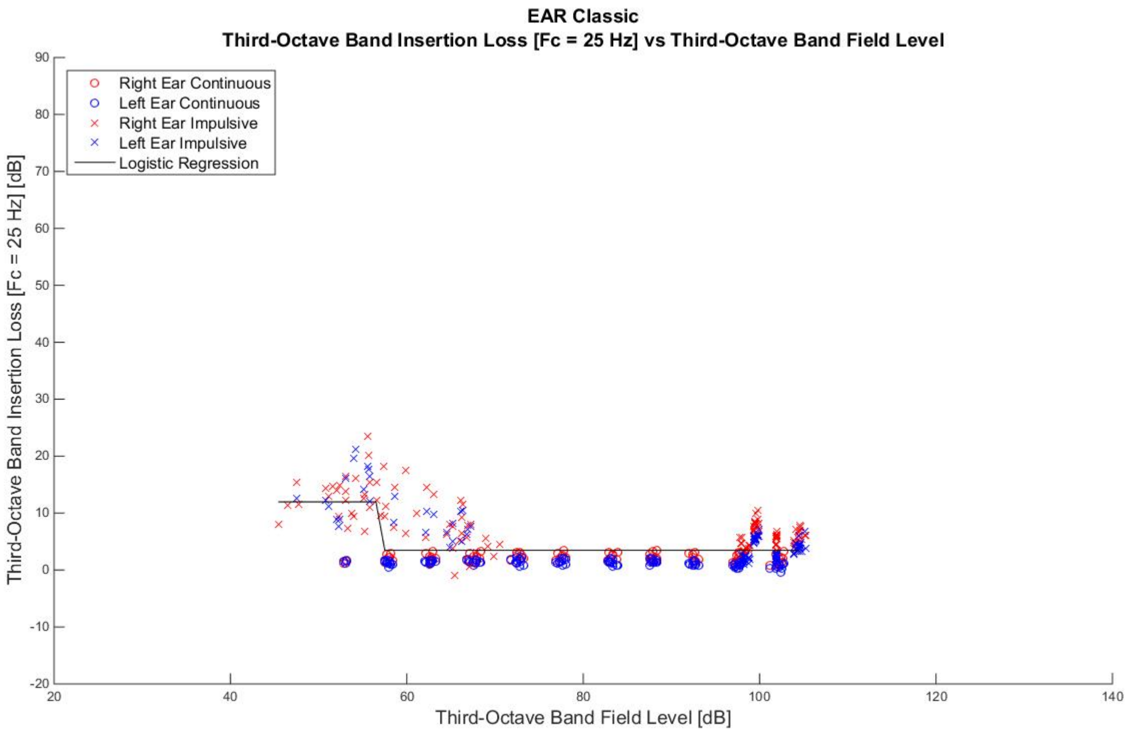

Figure A-33. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

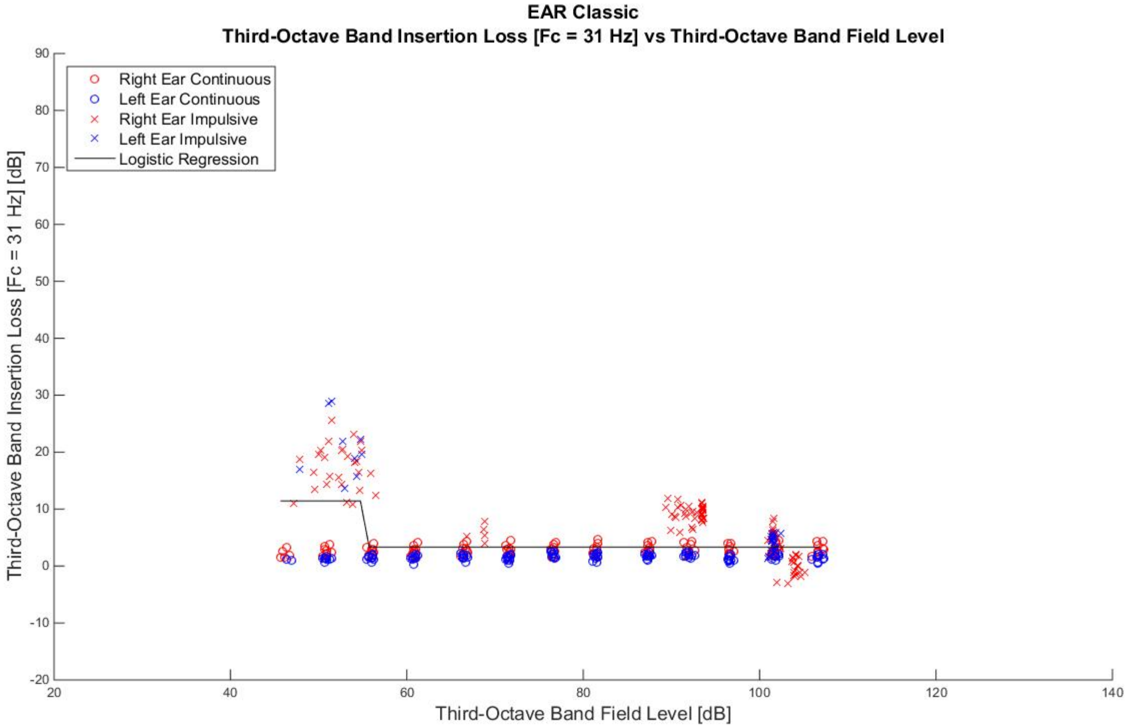

Figure A-34. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

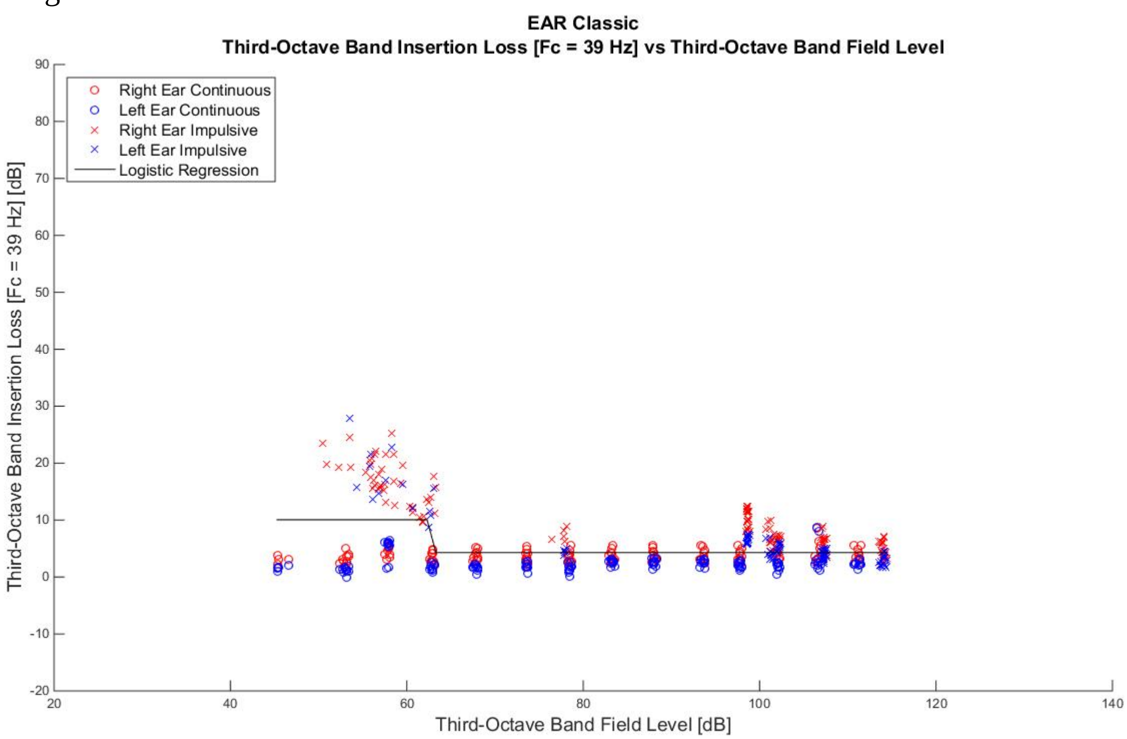

Figure A-35. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

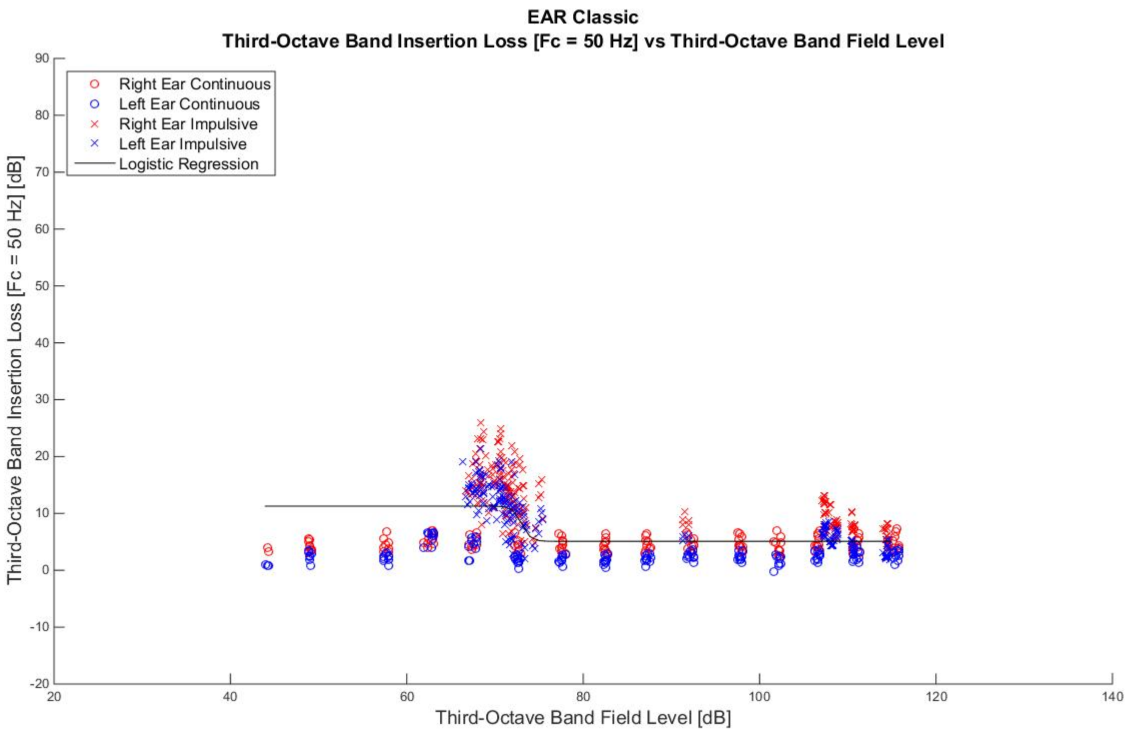

Figure A-36. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

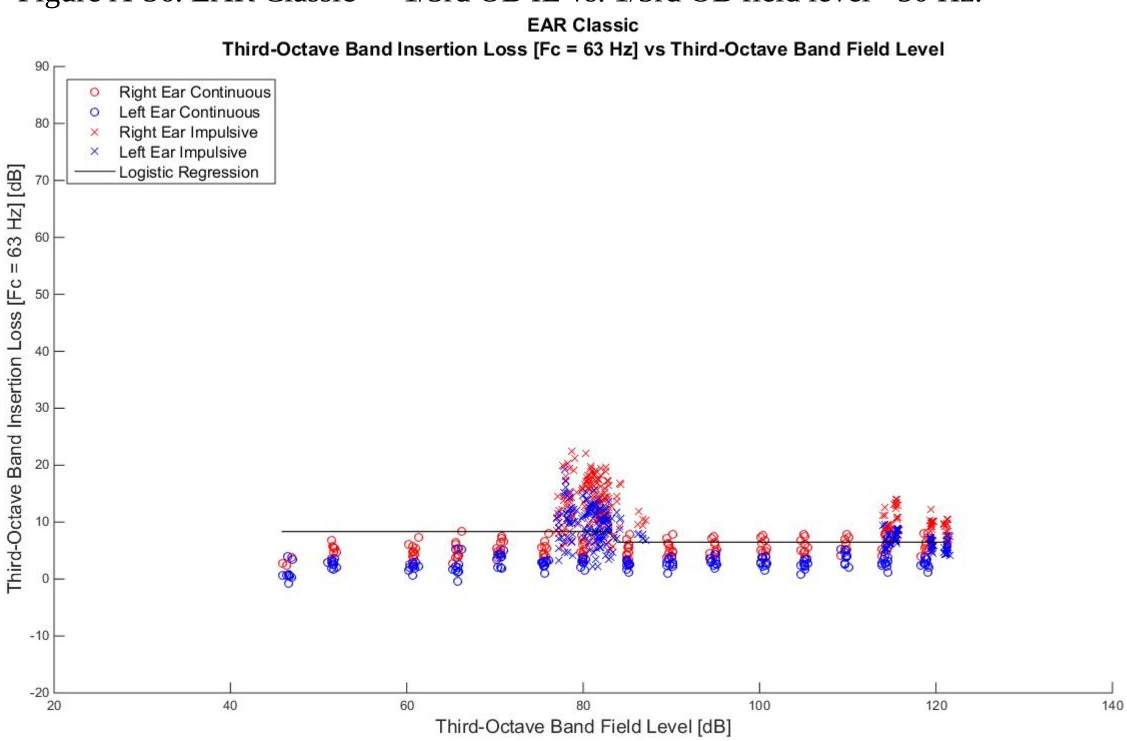

Figure A-37. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

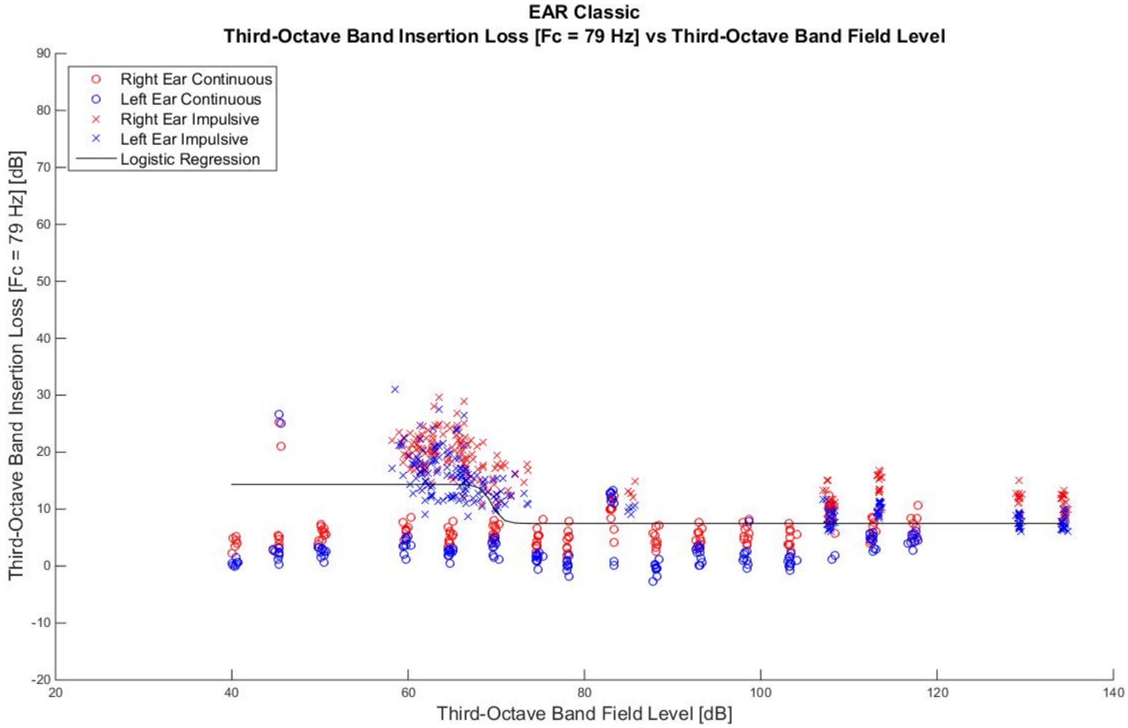

Figure A-38. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

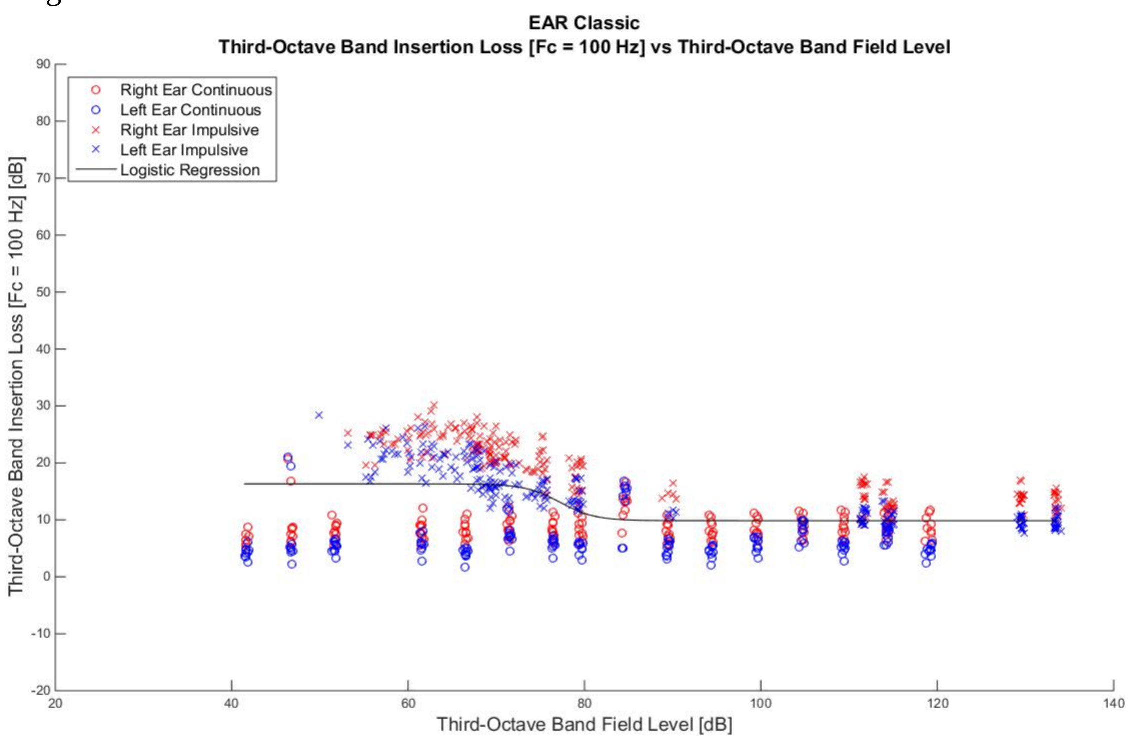

Figure A-39. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

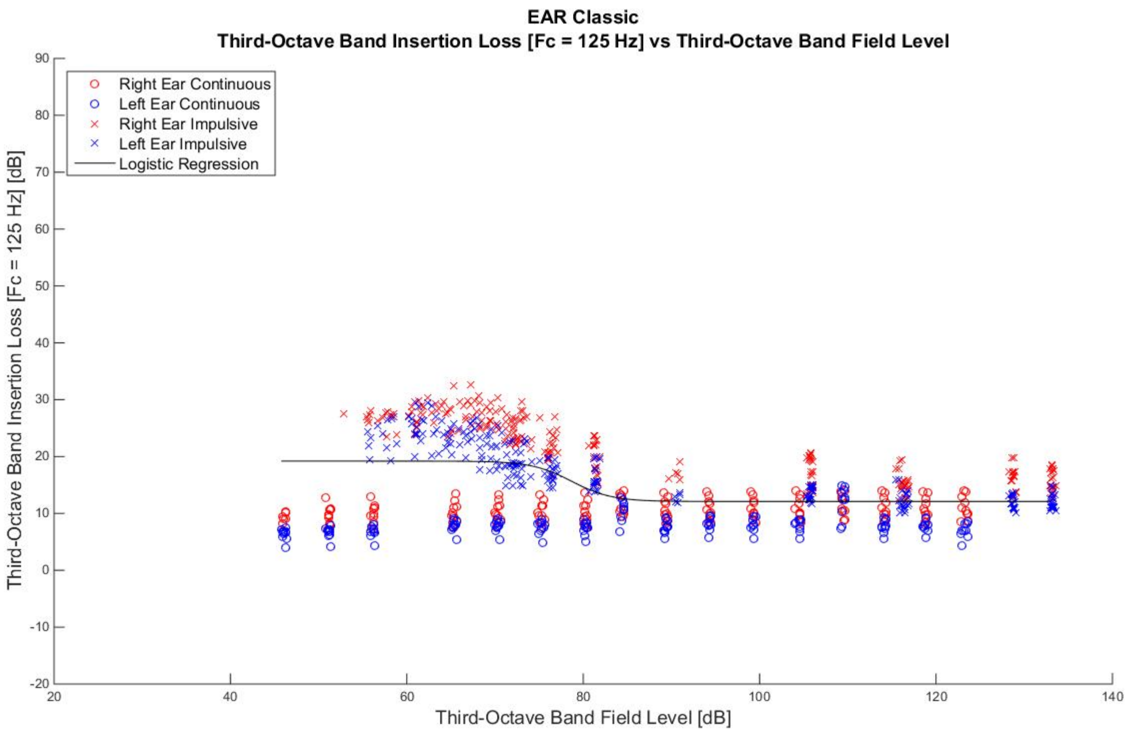

Figure A-40. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

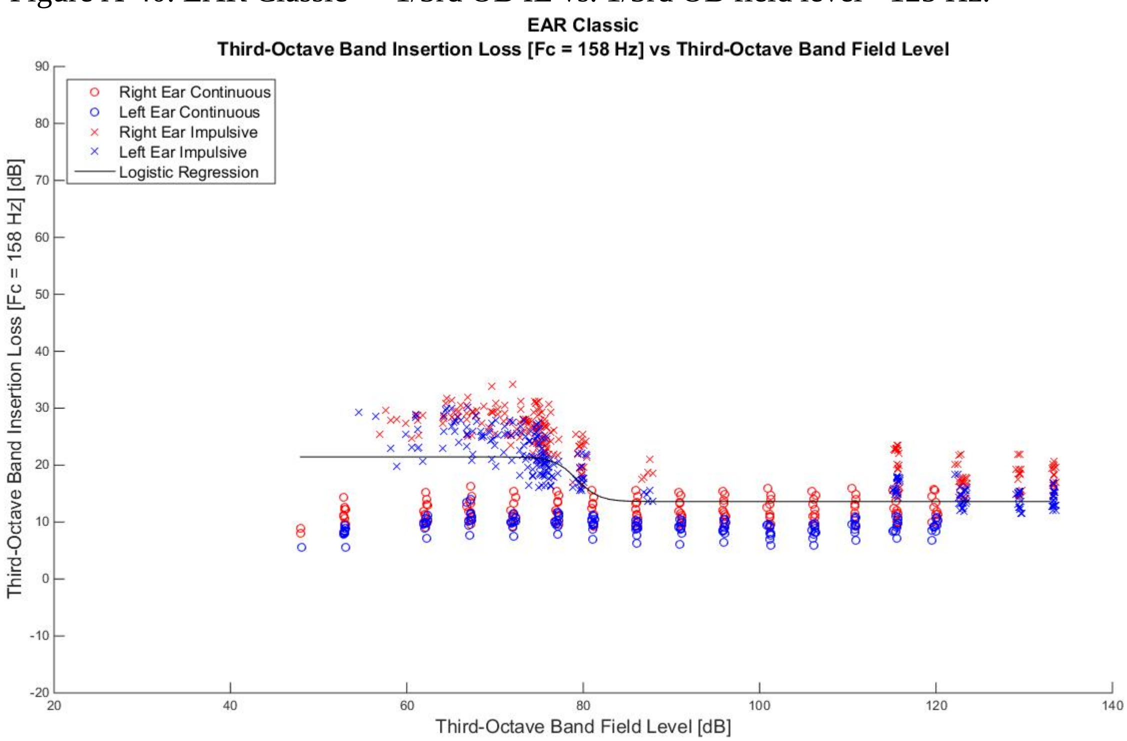

Figure A-41. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

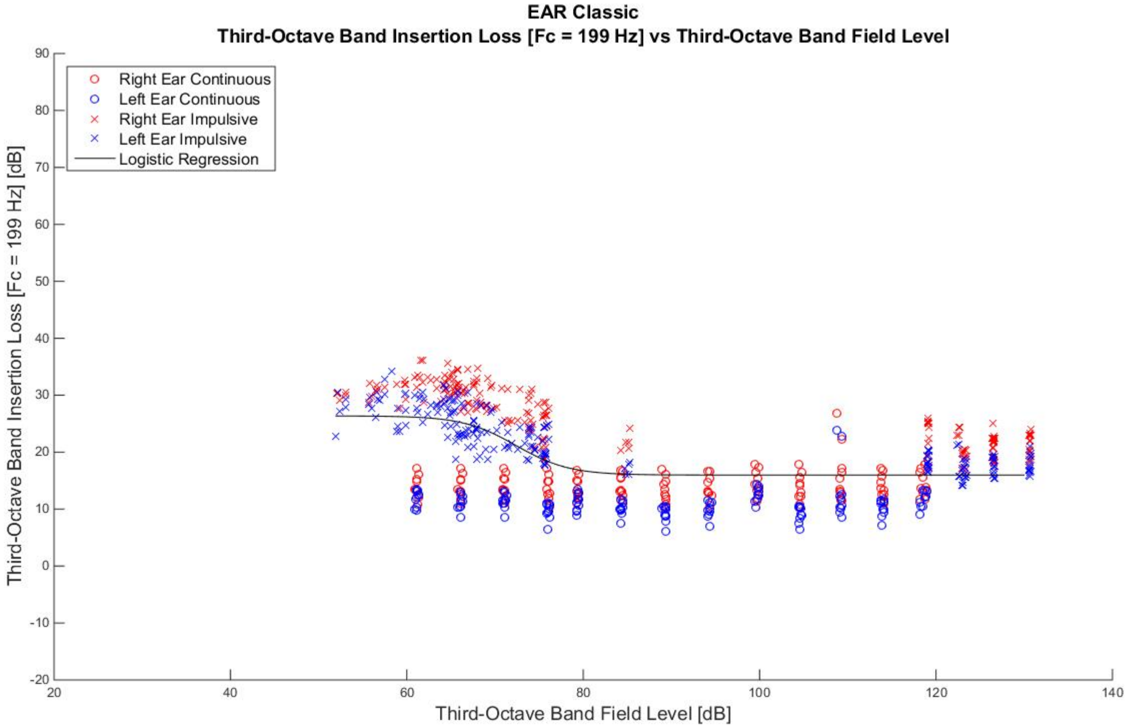

Figure A-42. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

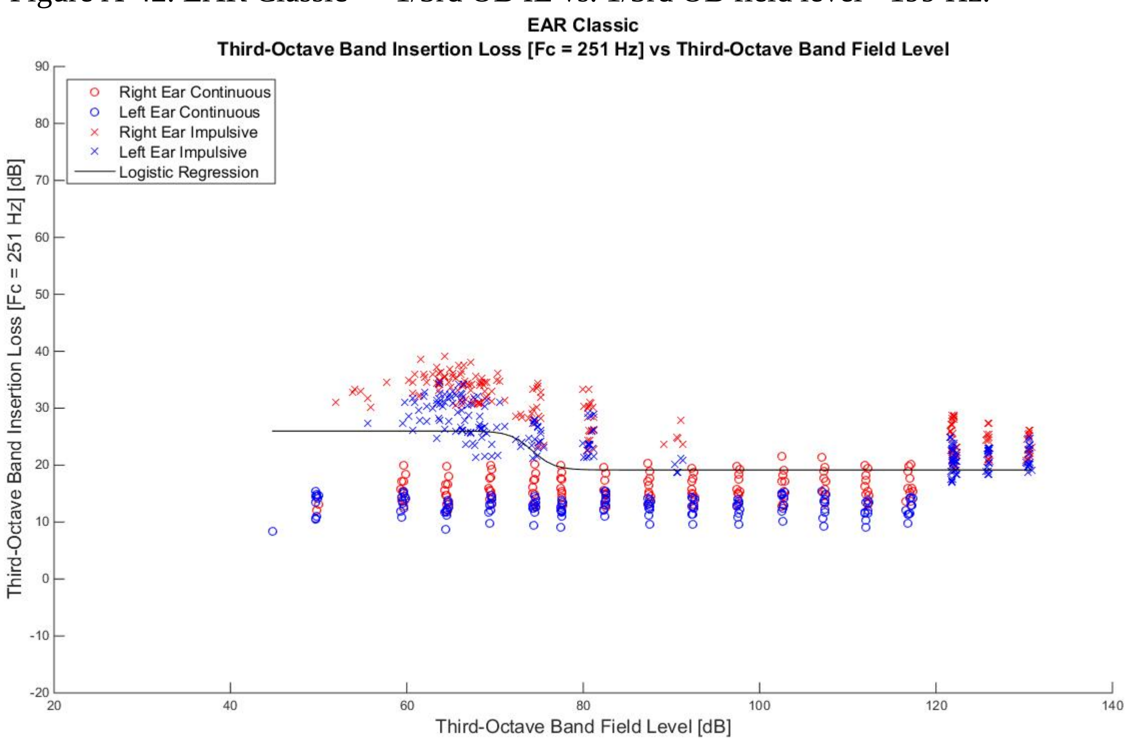

Figure A-43. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

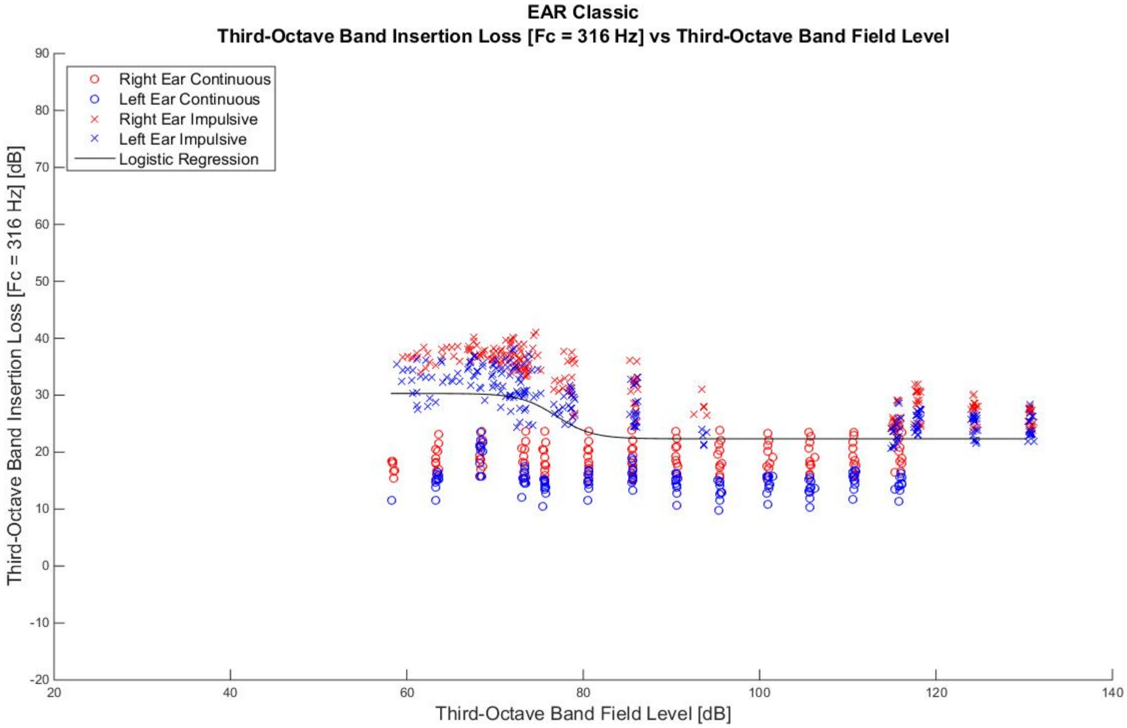

Figure A-44. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

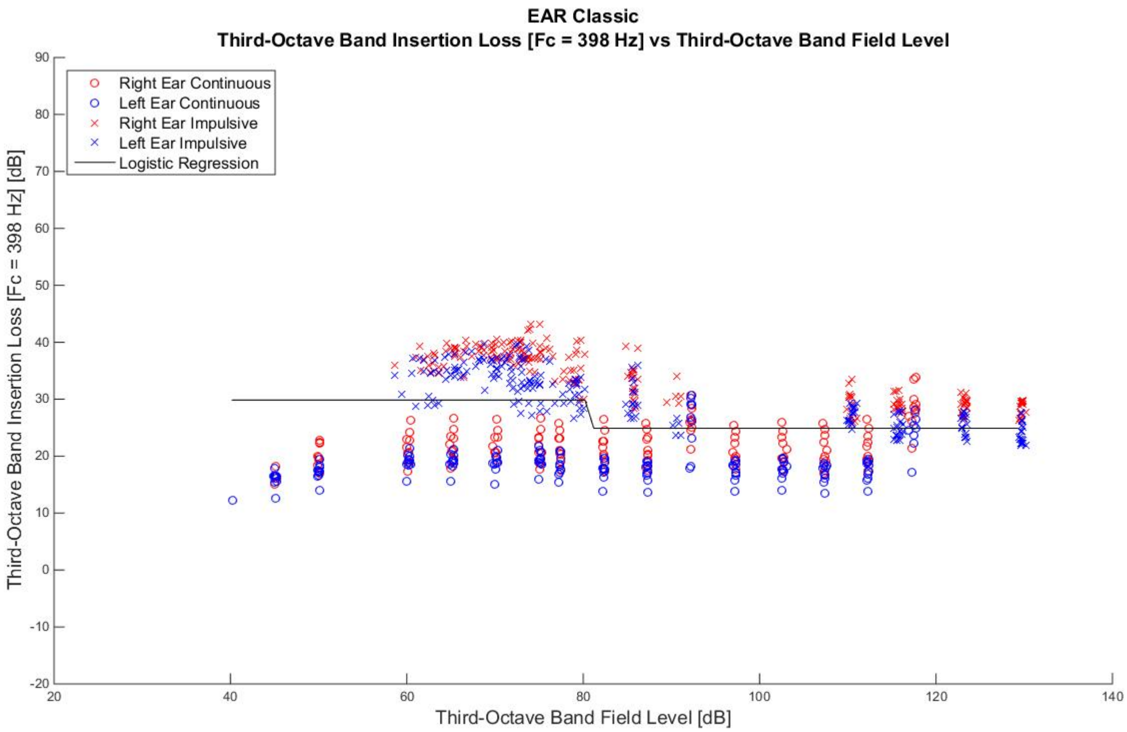

Figure A-45. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

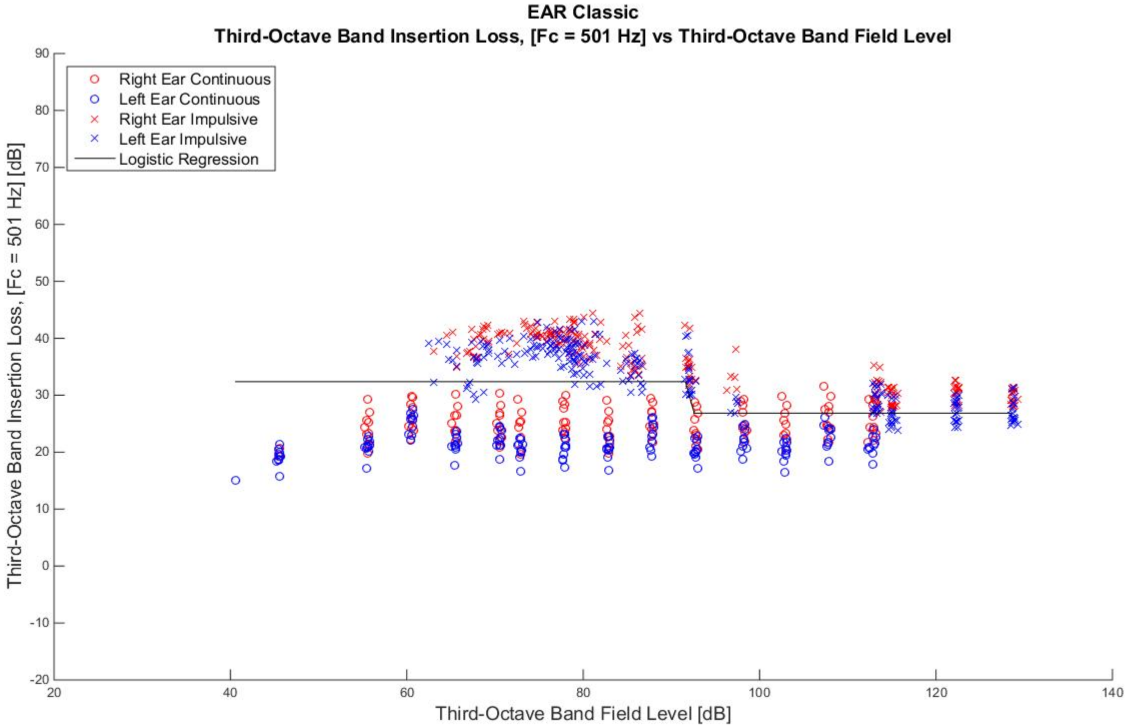

Figure A-46. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

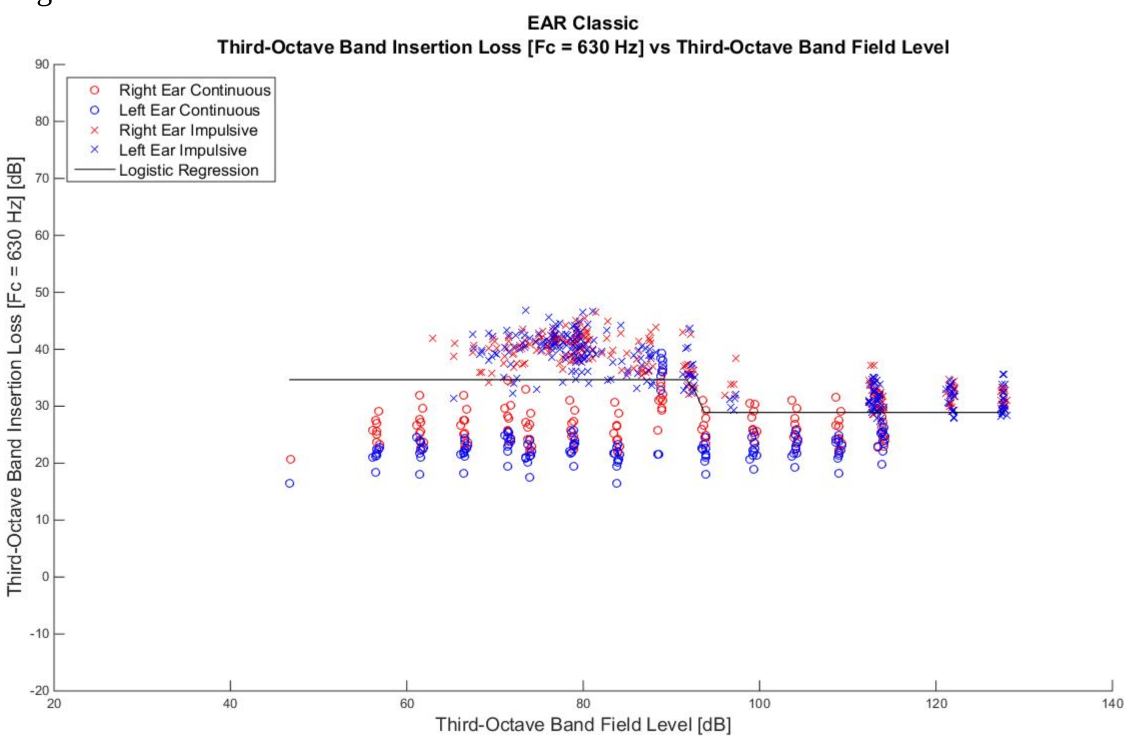

Figure A-47. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

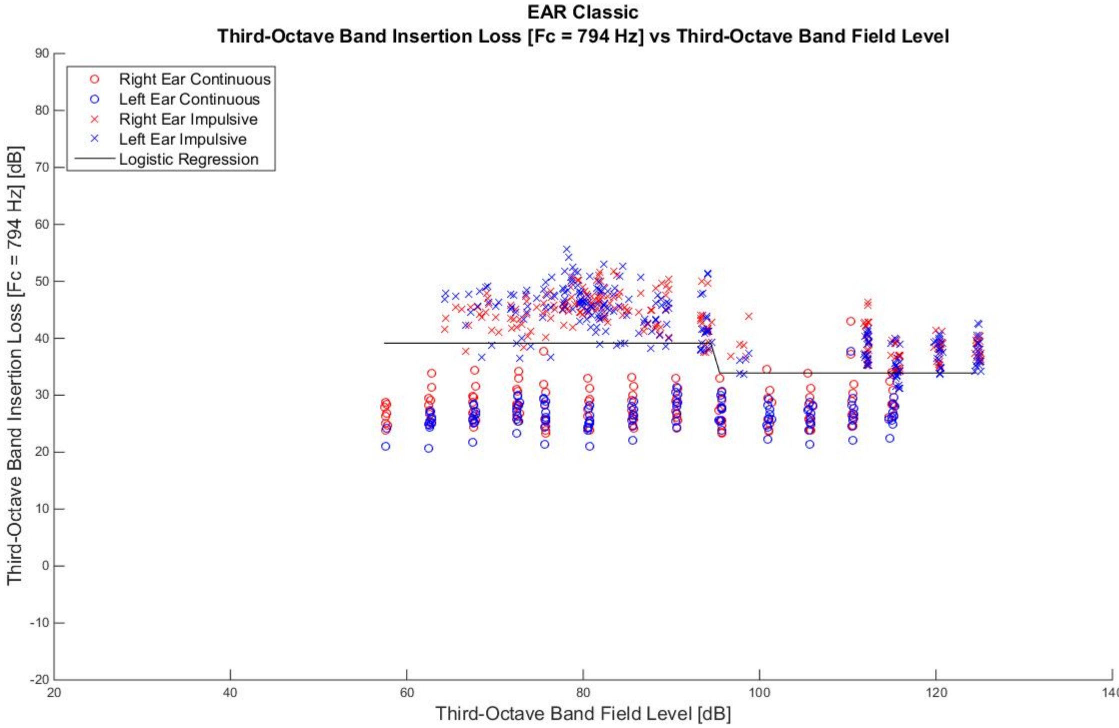

Figure A-48. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

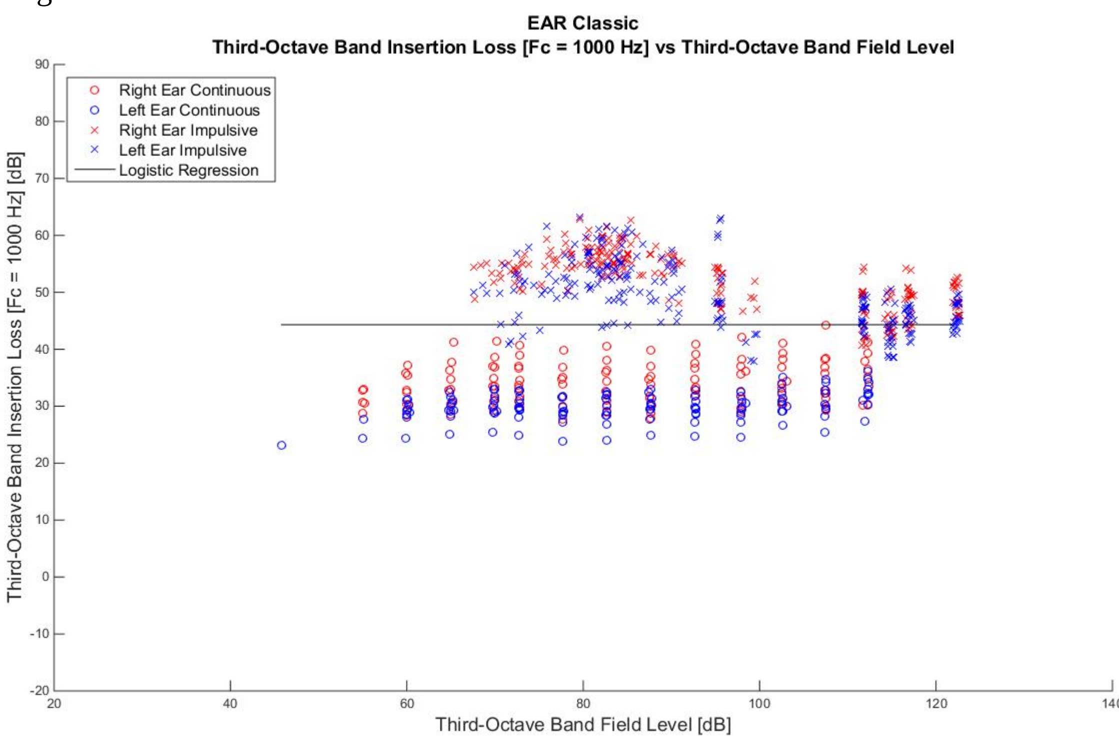

Figure A-49. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

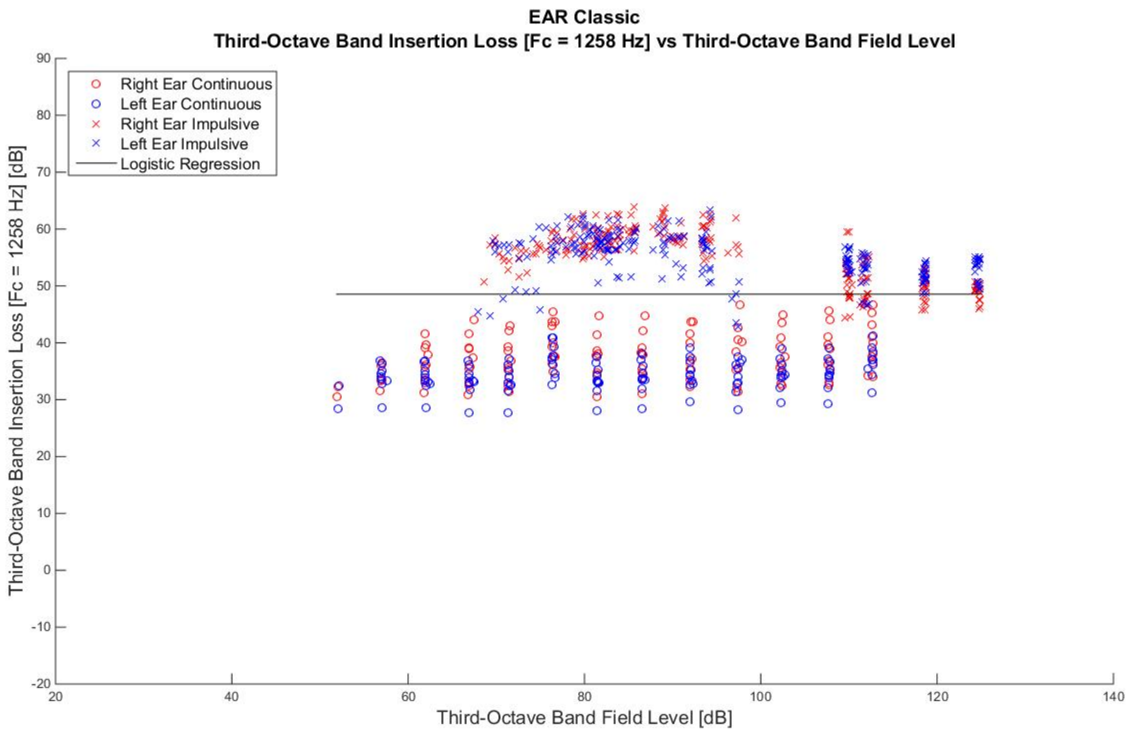

Figure A-50. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

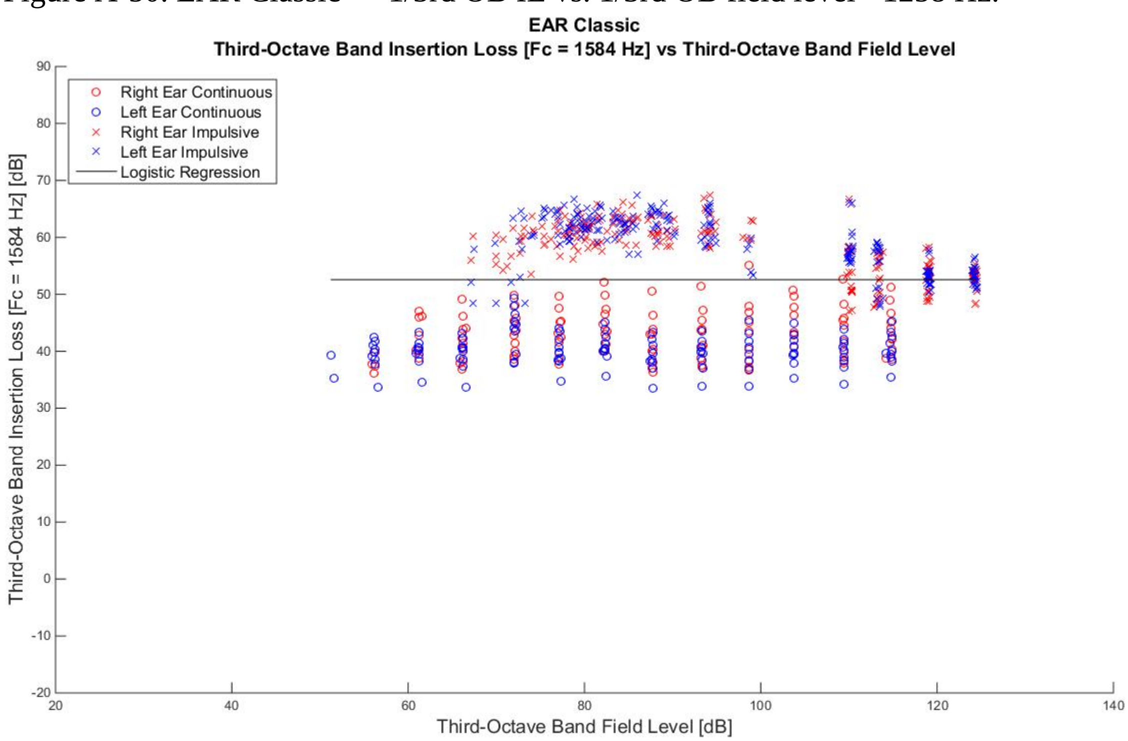

Figure A-51. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

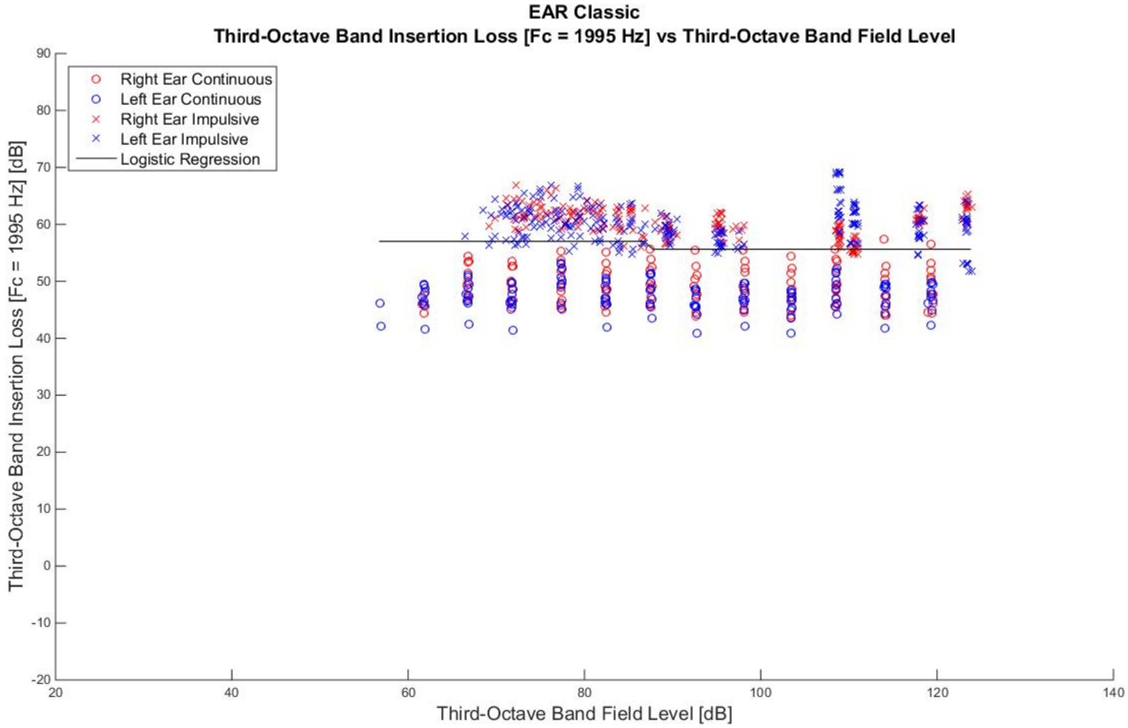

Figure A-52. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

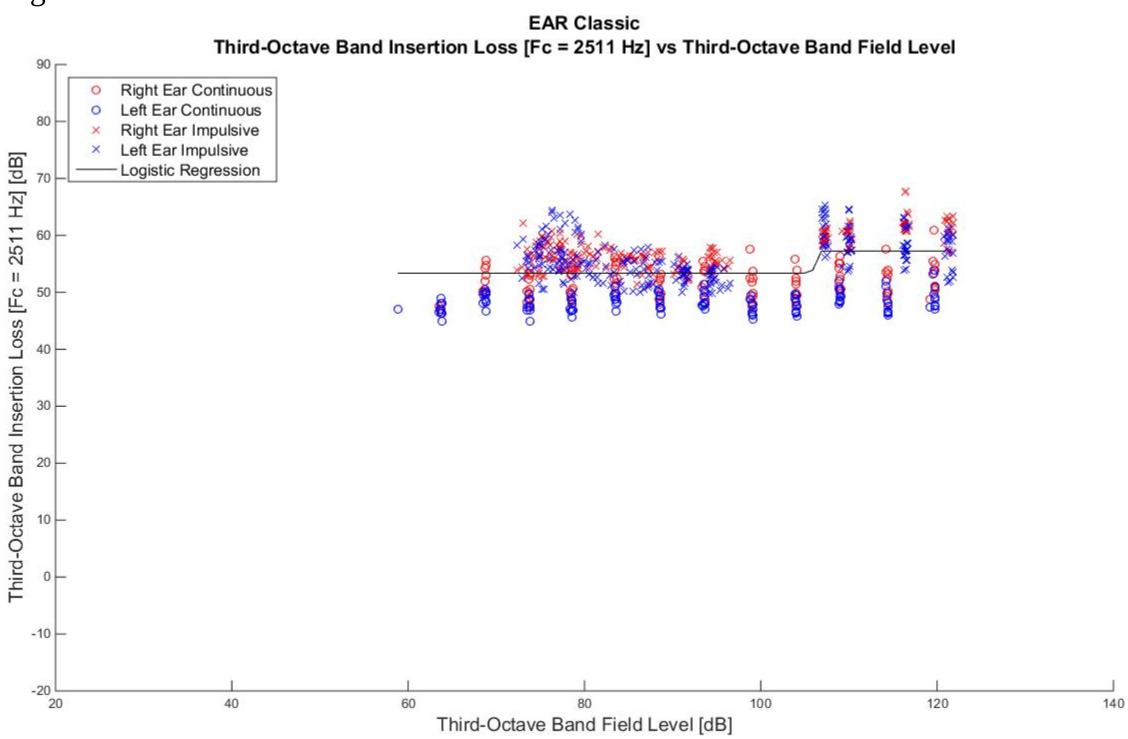

Figure A-53. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

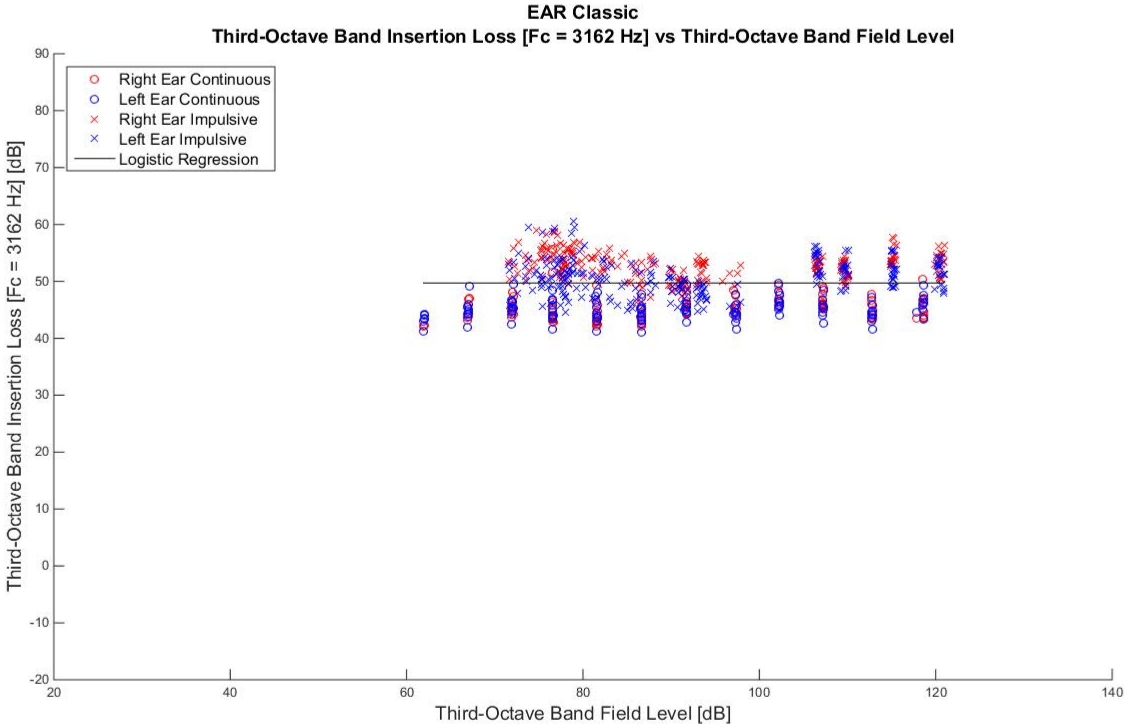

Figure A-54. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

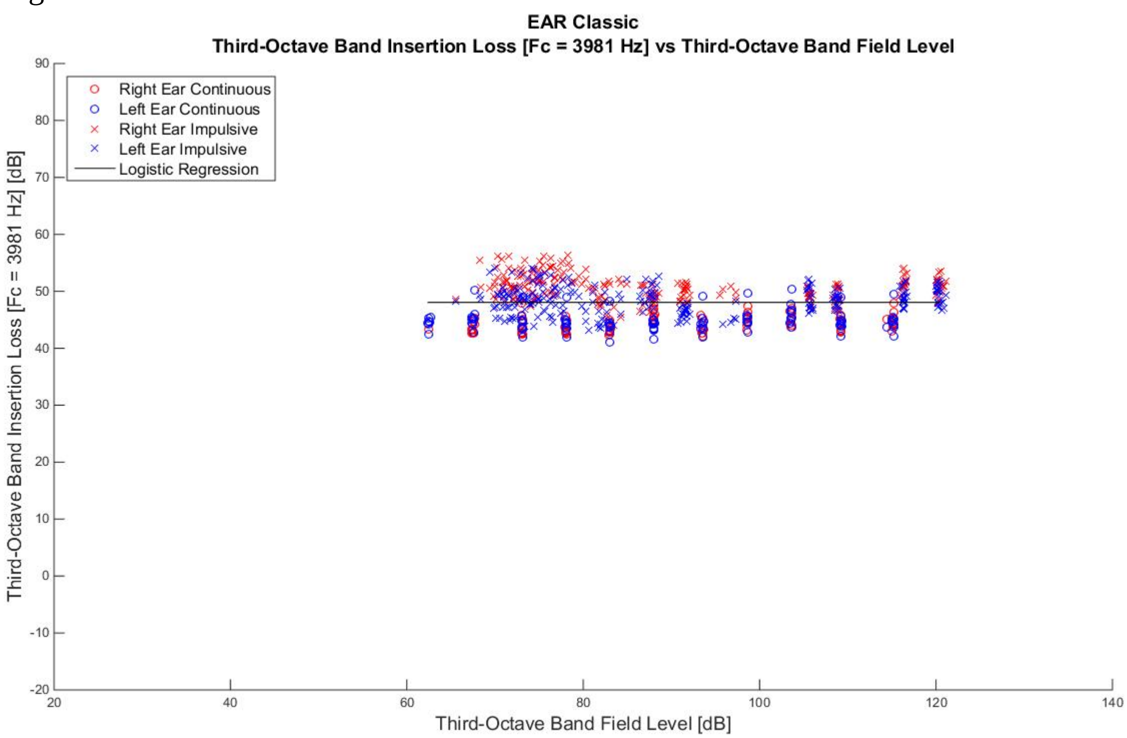

Figure A-55. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

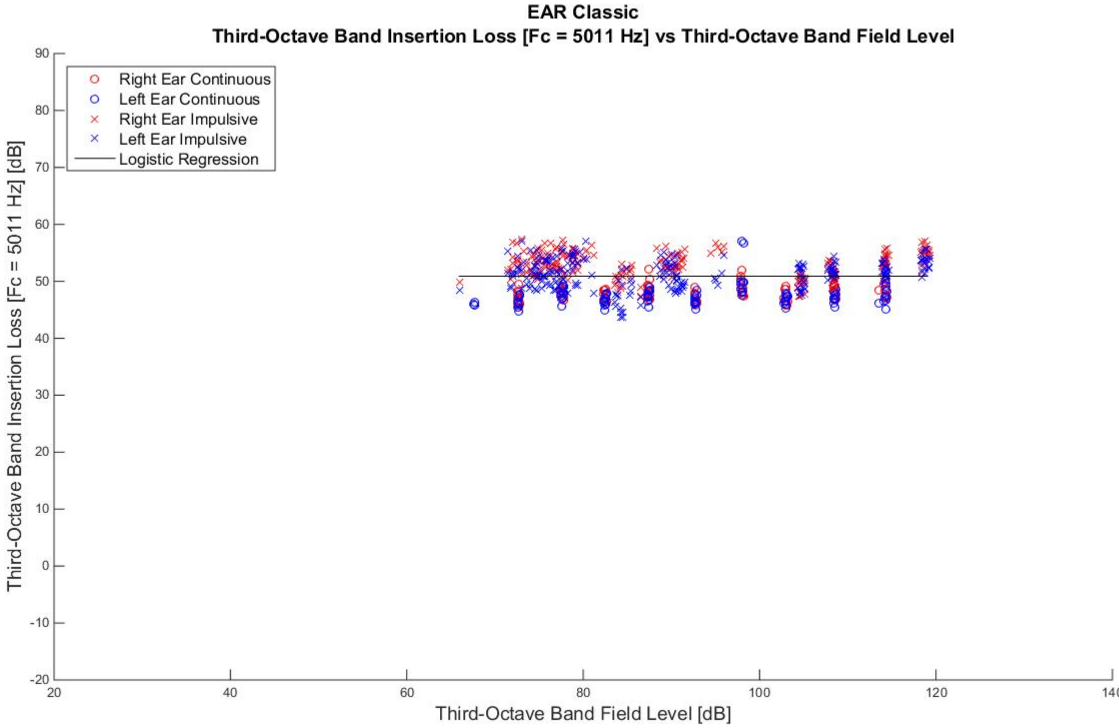

Figure A-56. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

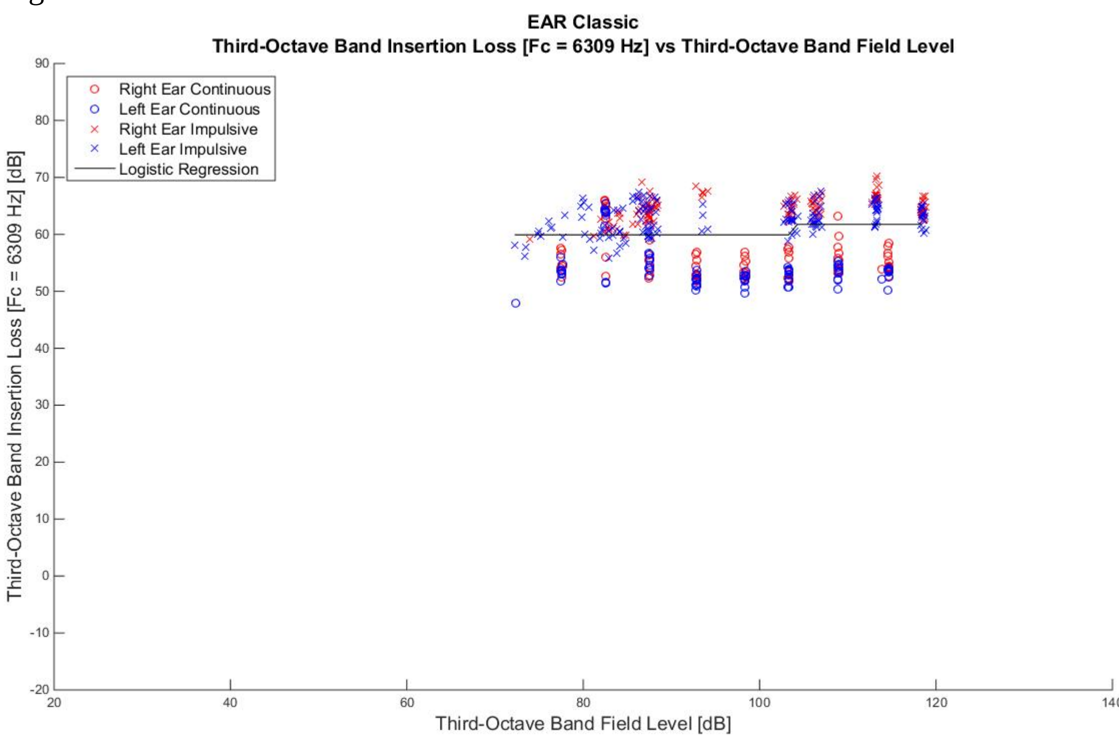

Figure A-57. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

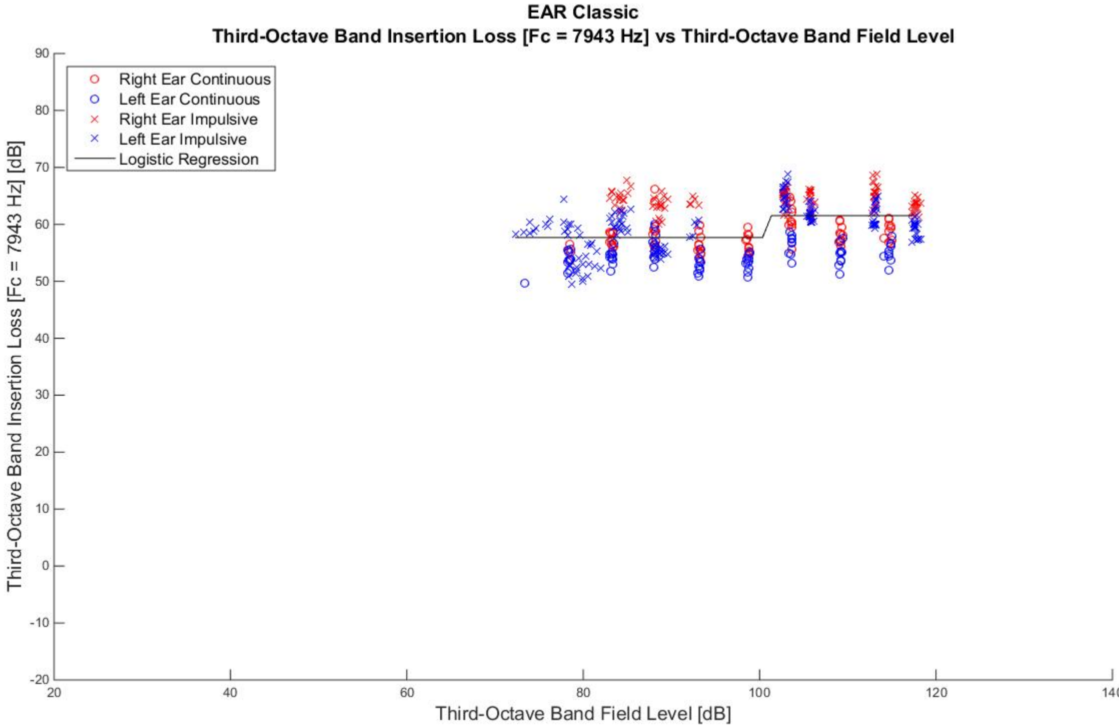

Figure A-58. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

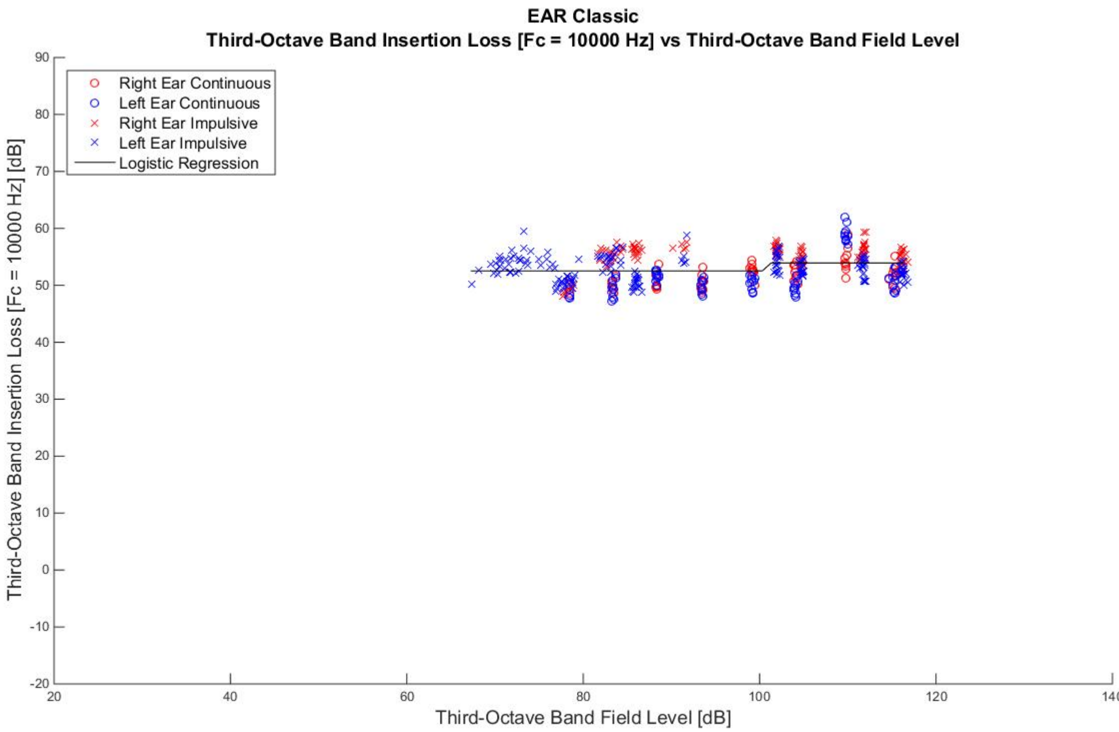

Figure A-59. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

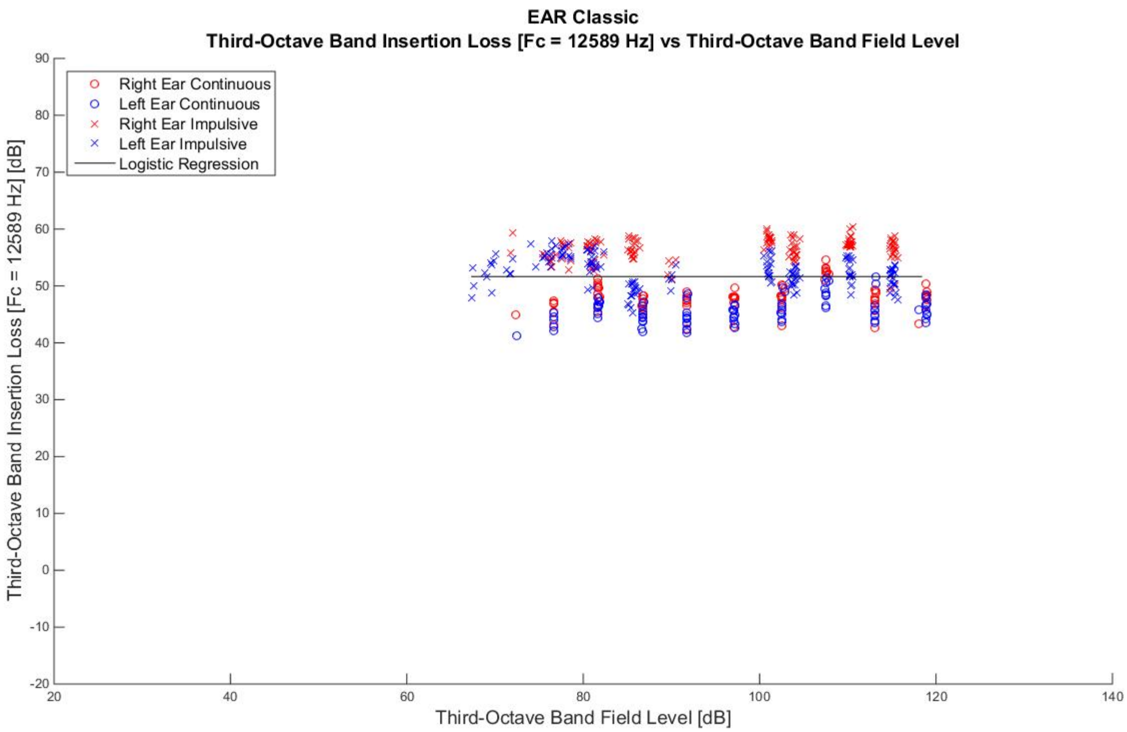

Figure A-60. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

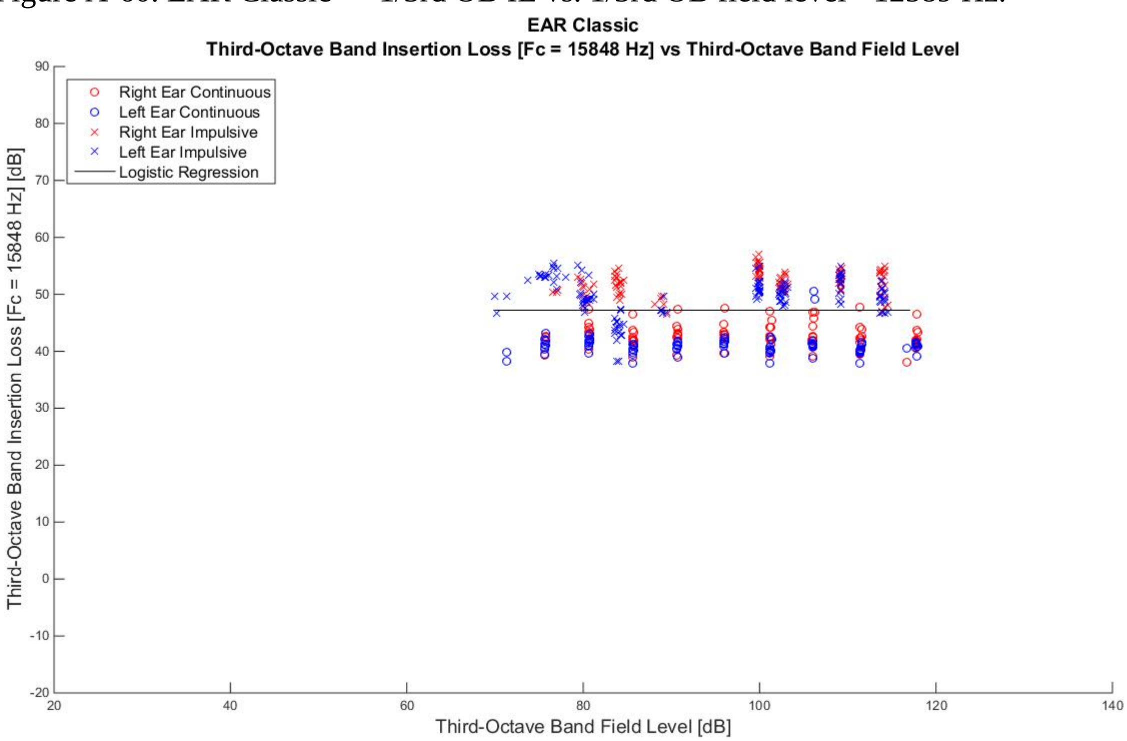

Figure A-61. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

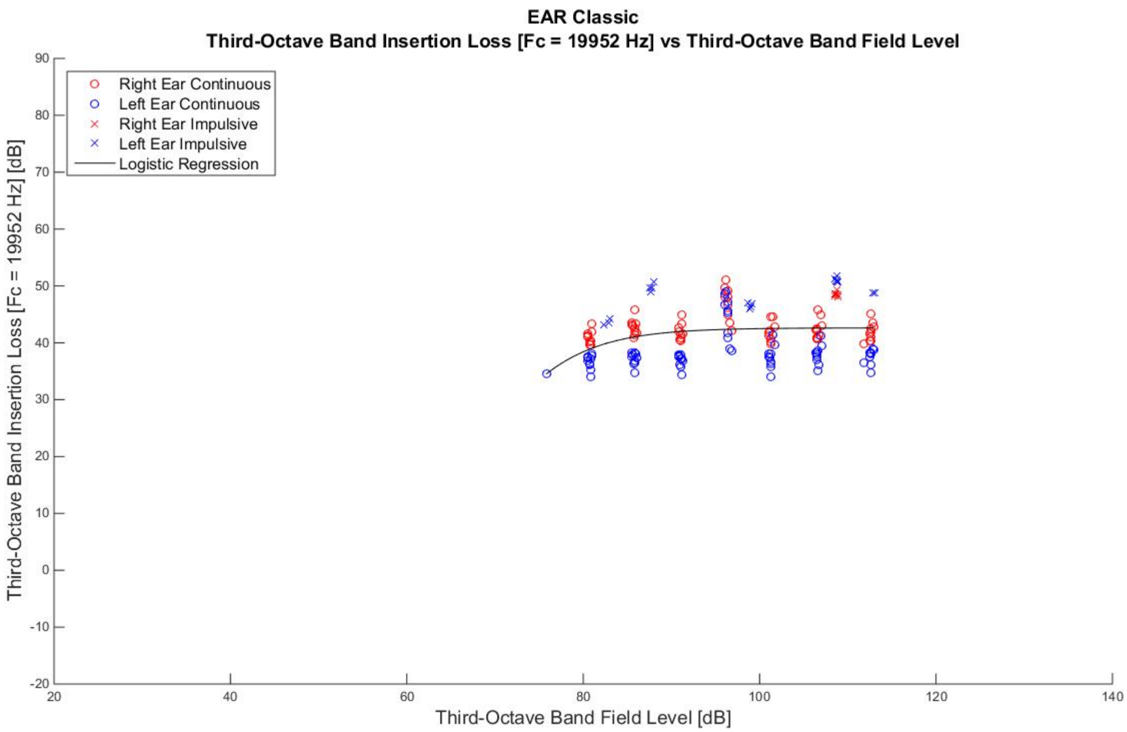

Figure A-62. EAR Classic™ - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

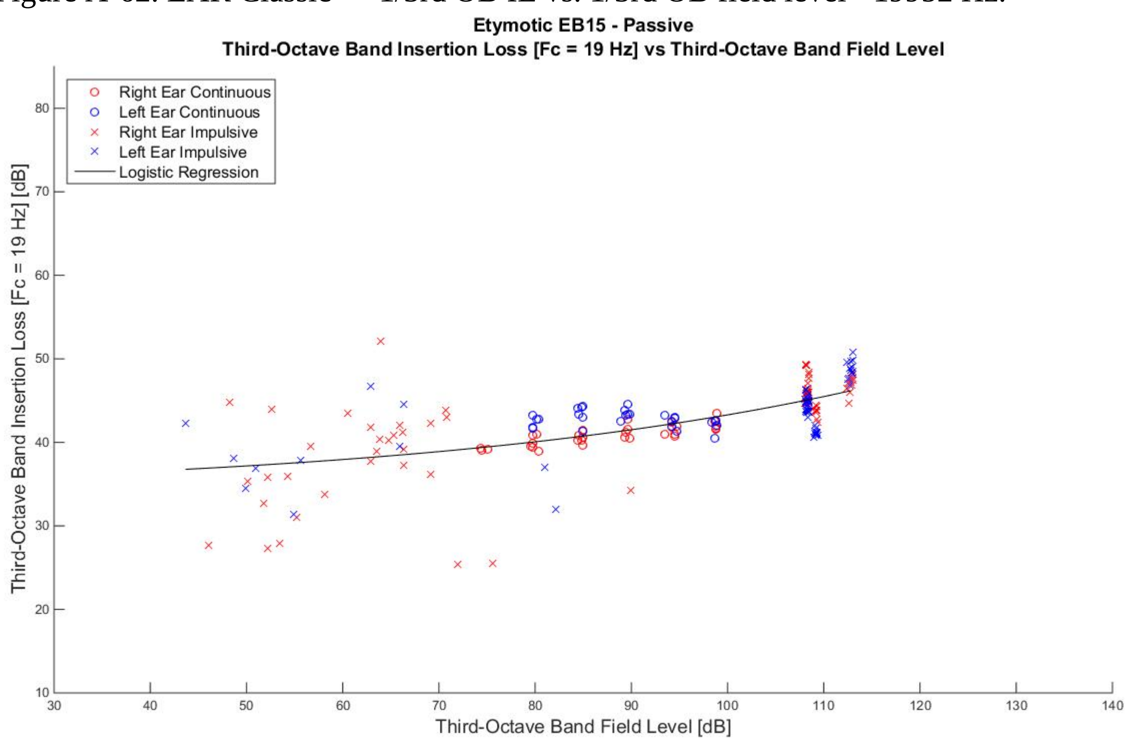

Figure A-63. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

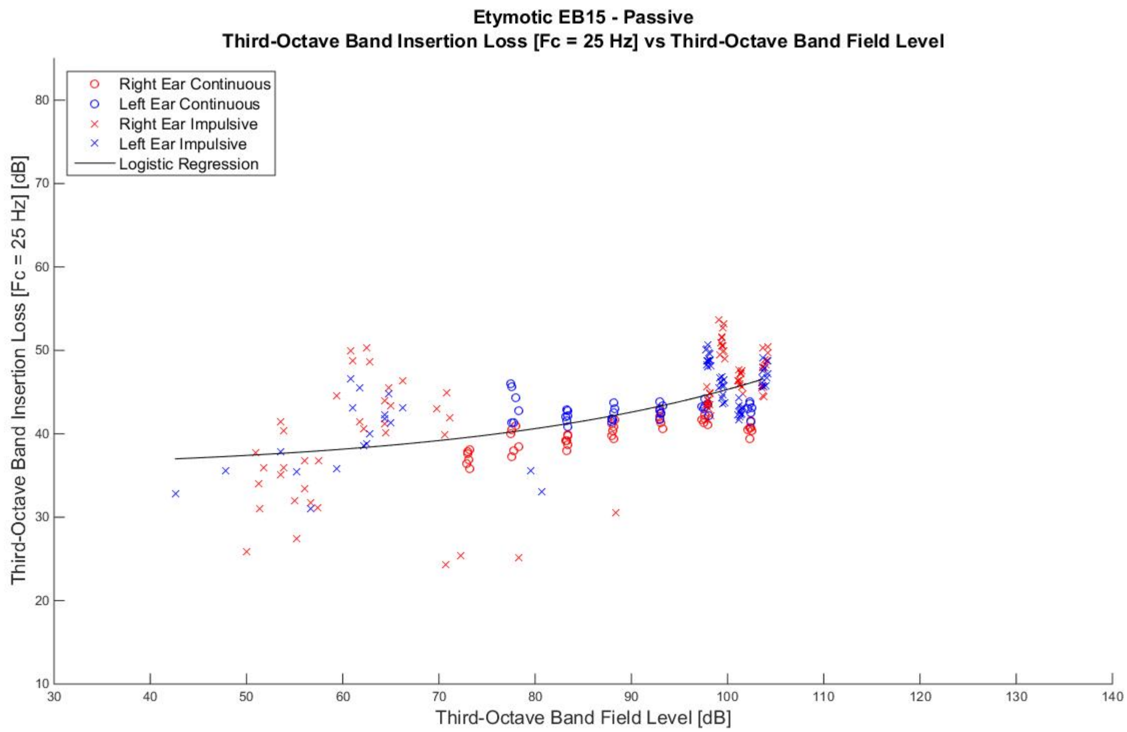

Figure A-64. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

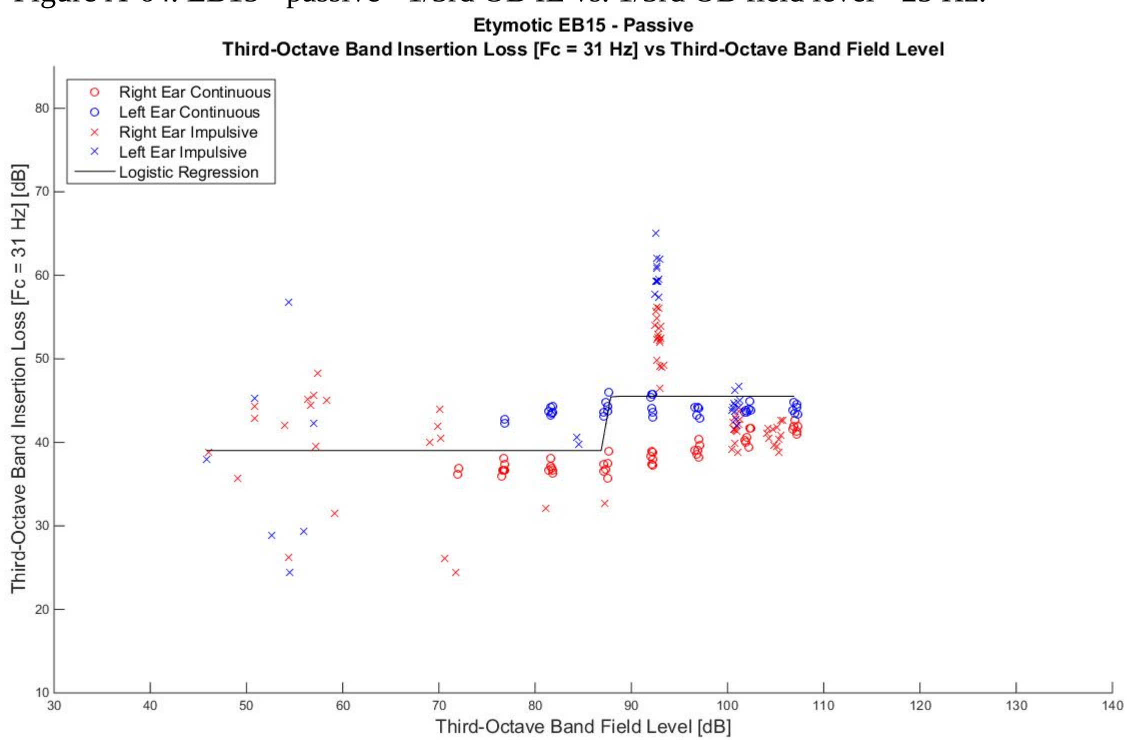

Figure A-65. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

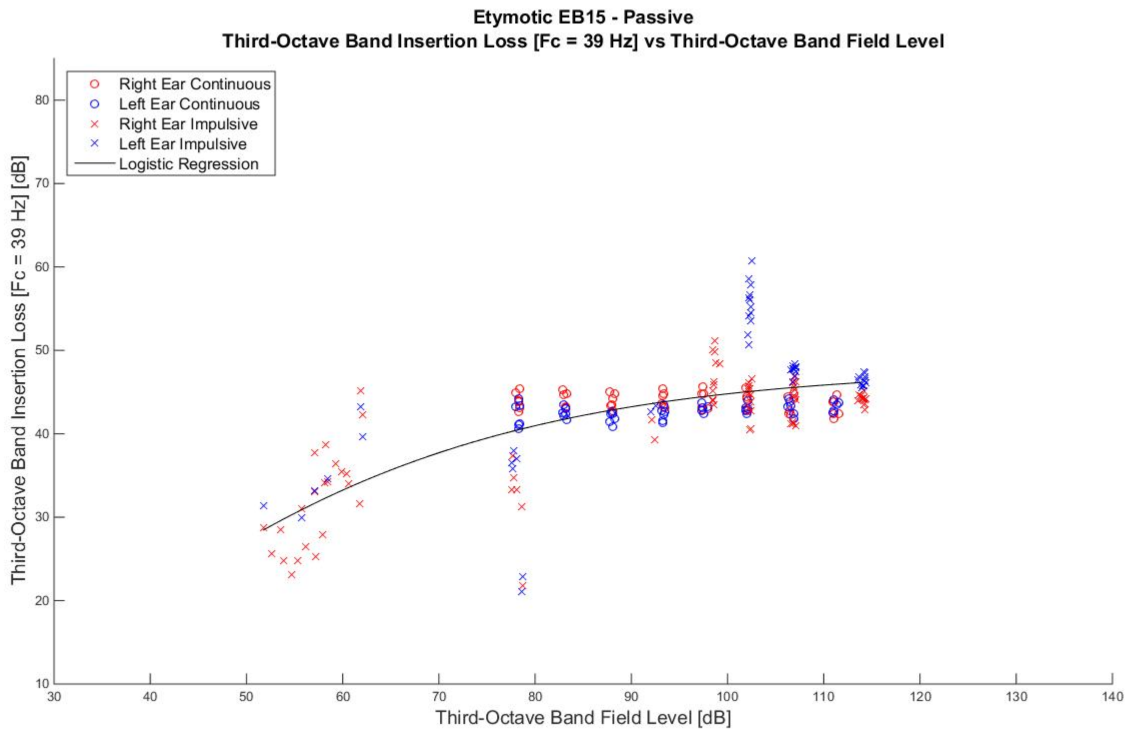

Figure A-66. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

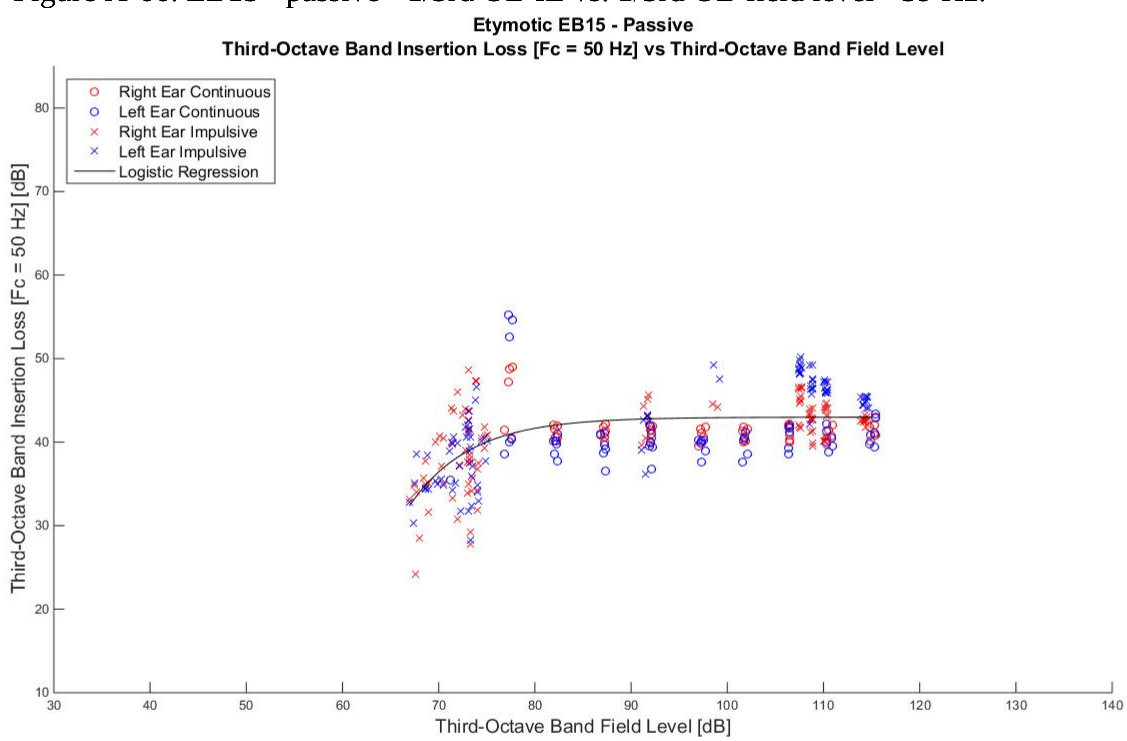

Figure A-67. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

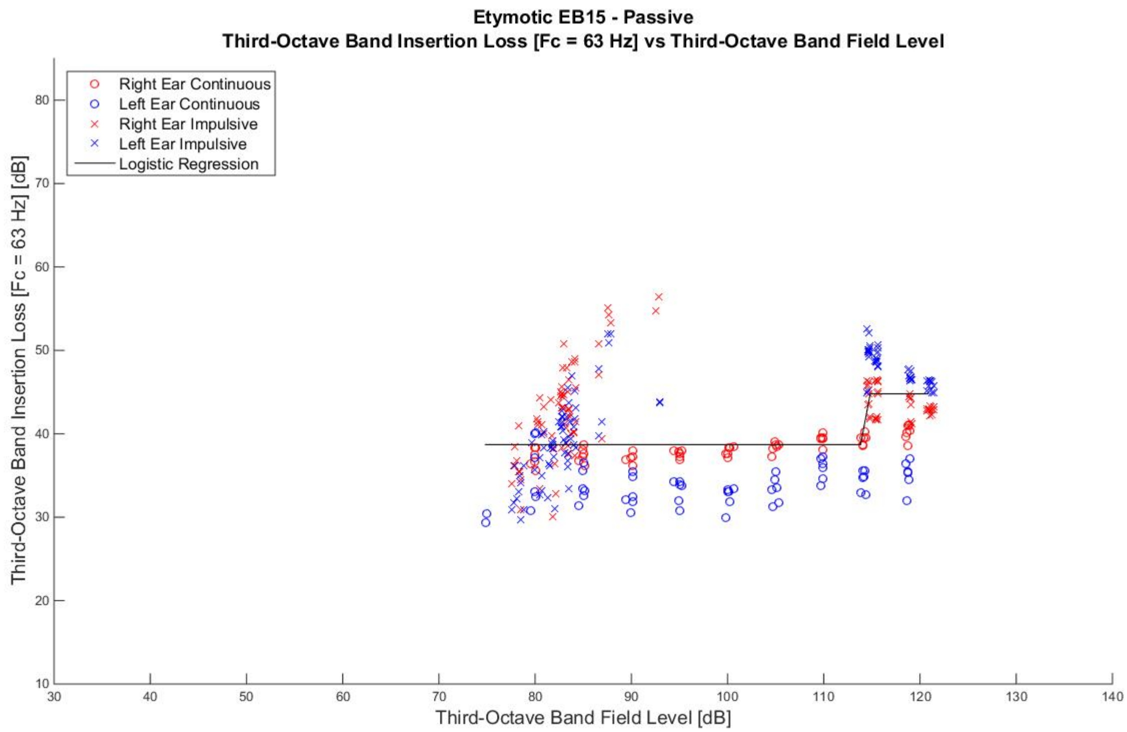

Figure A-68. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

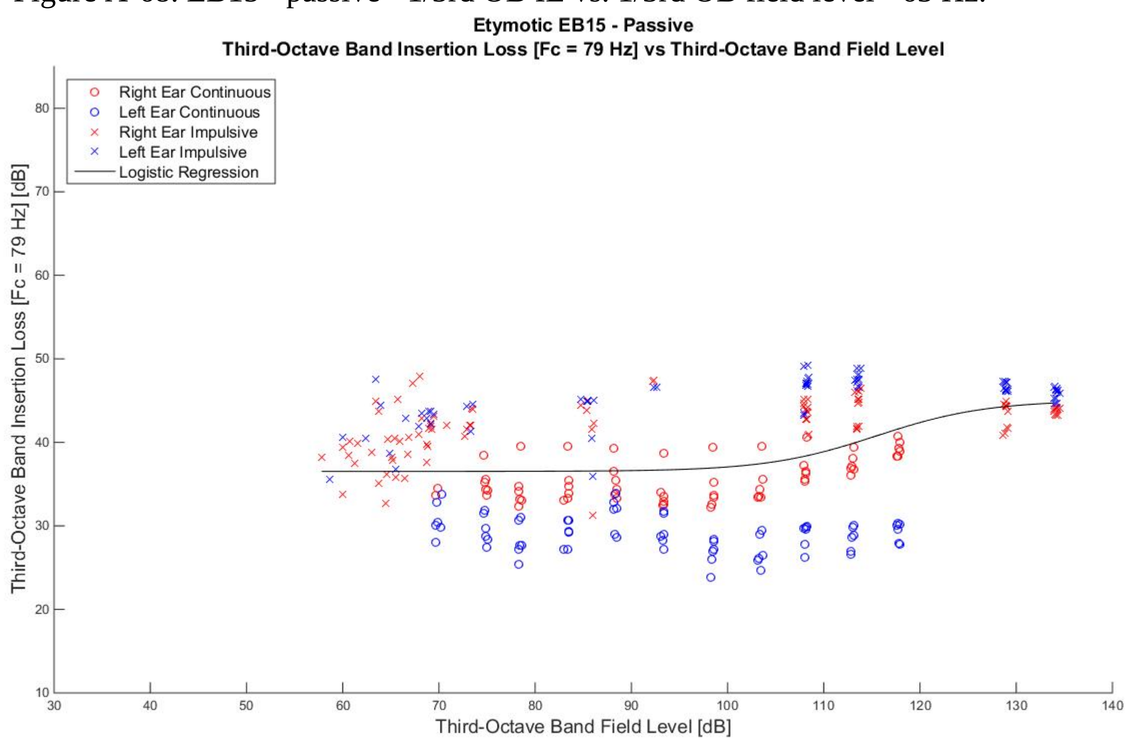

Figure A-69. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

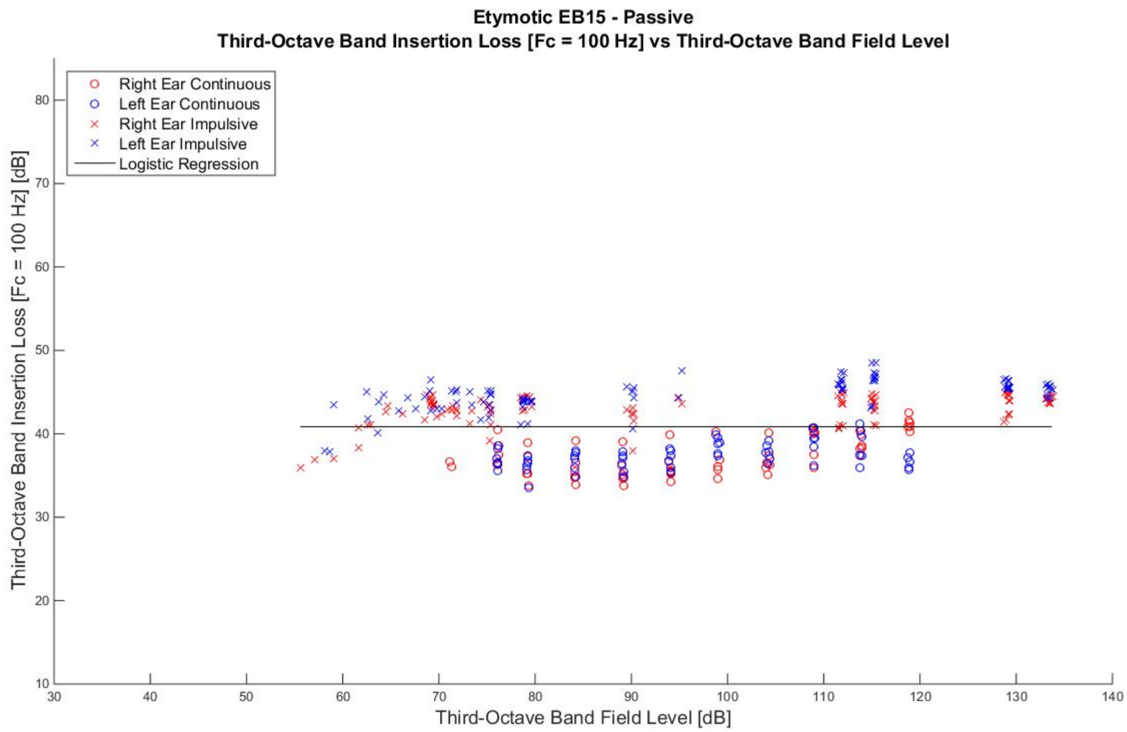

Figure A-70. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

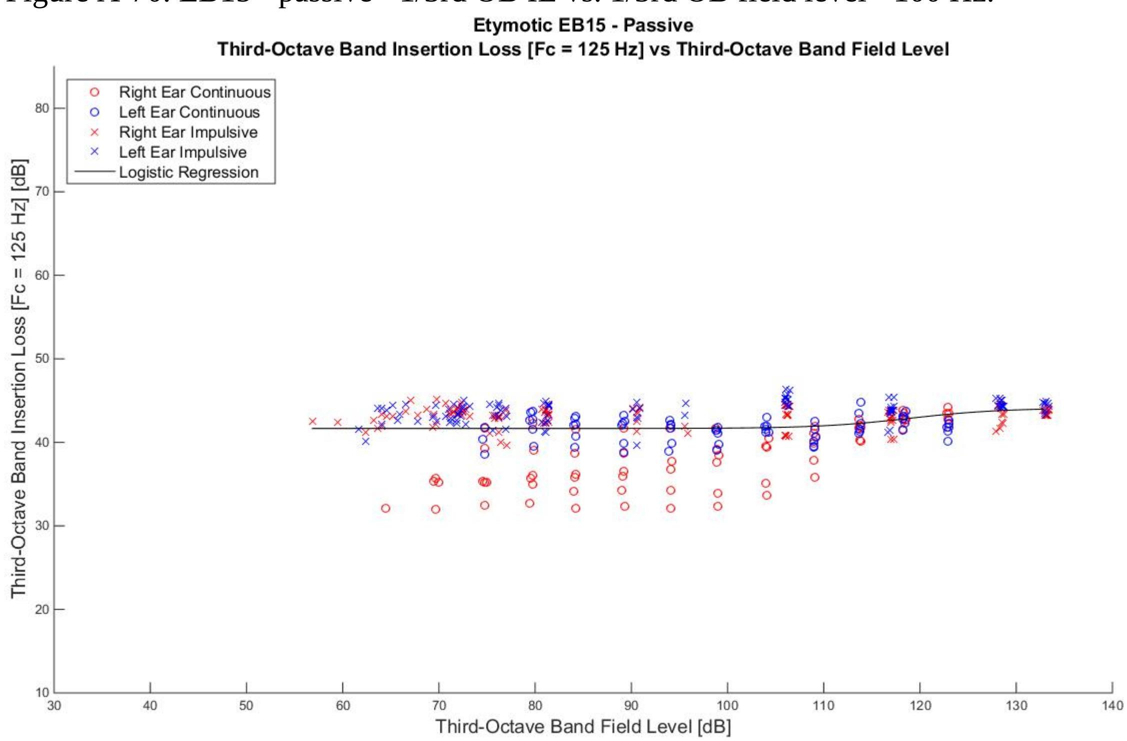

Figure A-71. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

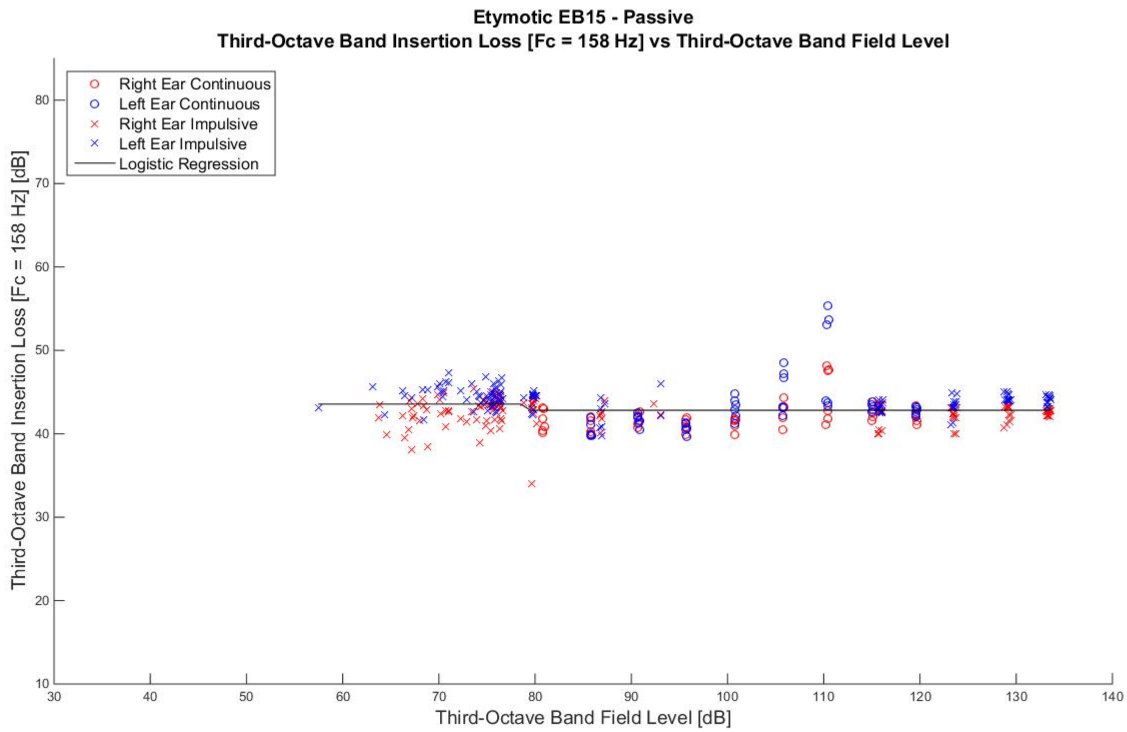

Figure A-72. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

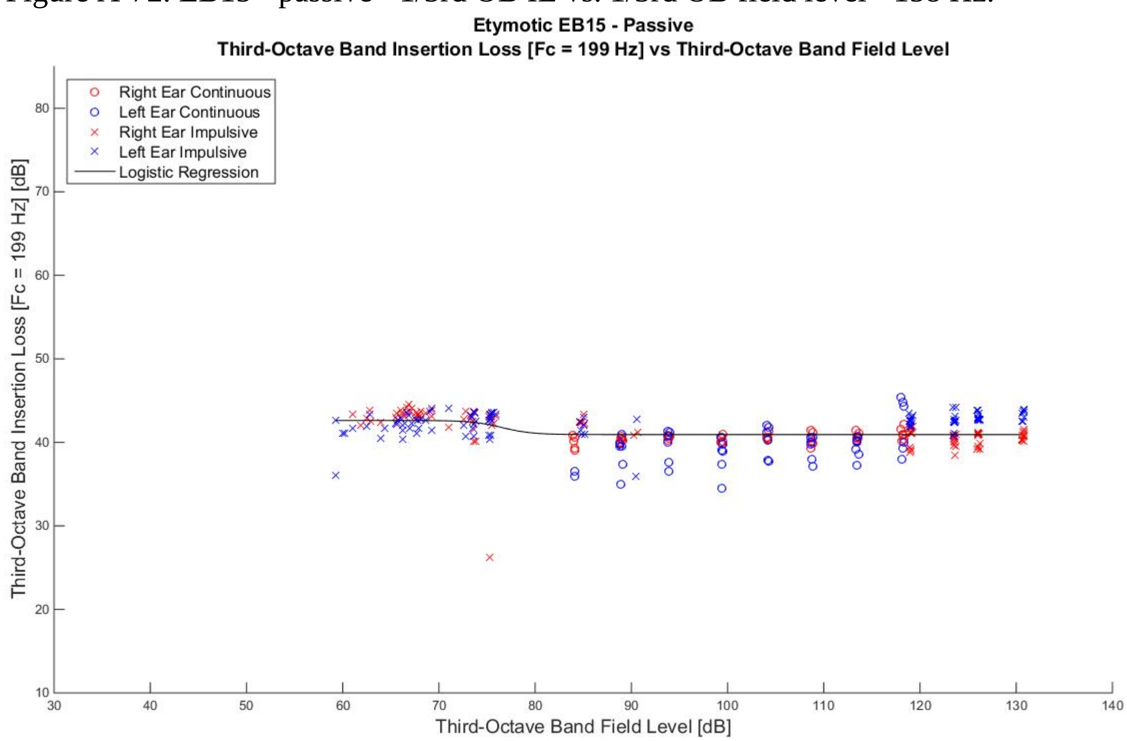

Figure A-73. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

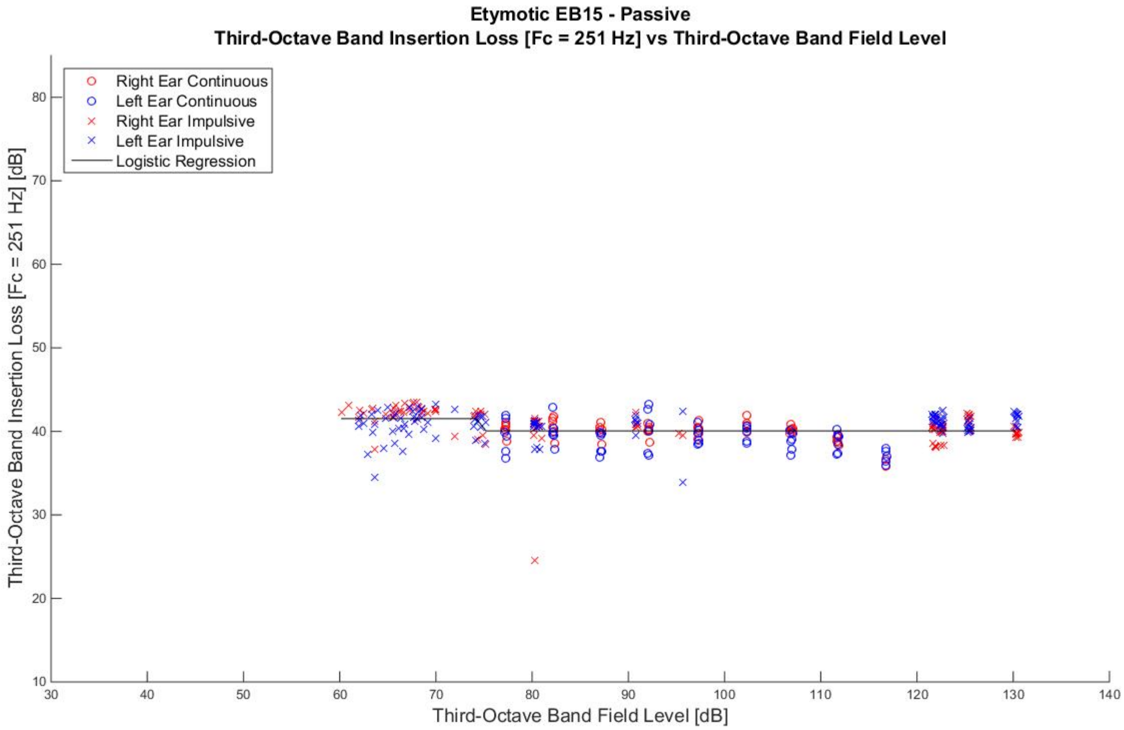

Figure A-74. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

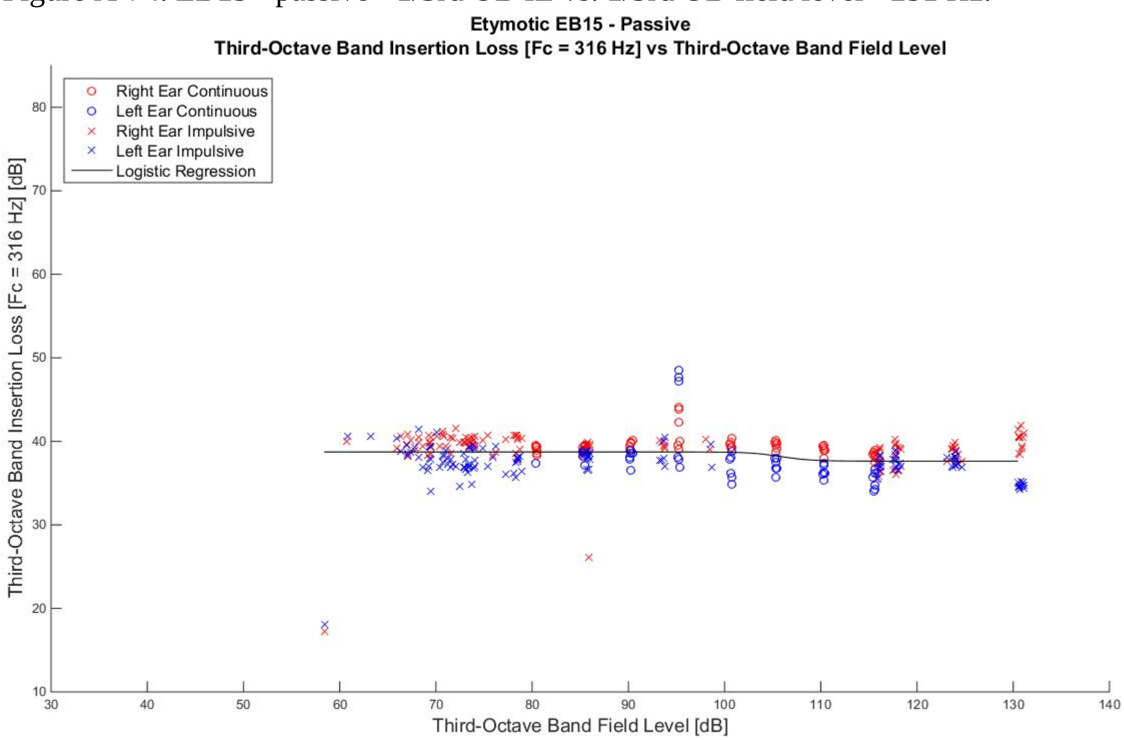

Figure A-75. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

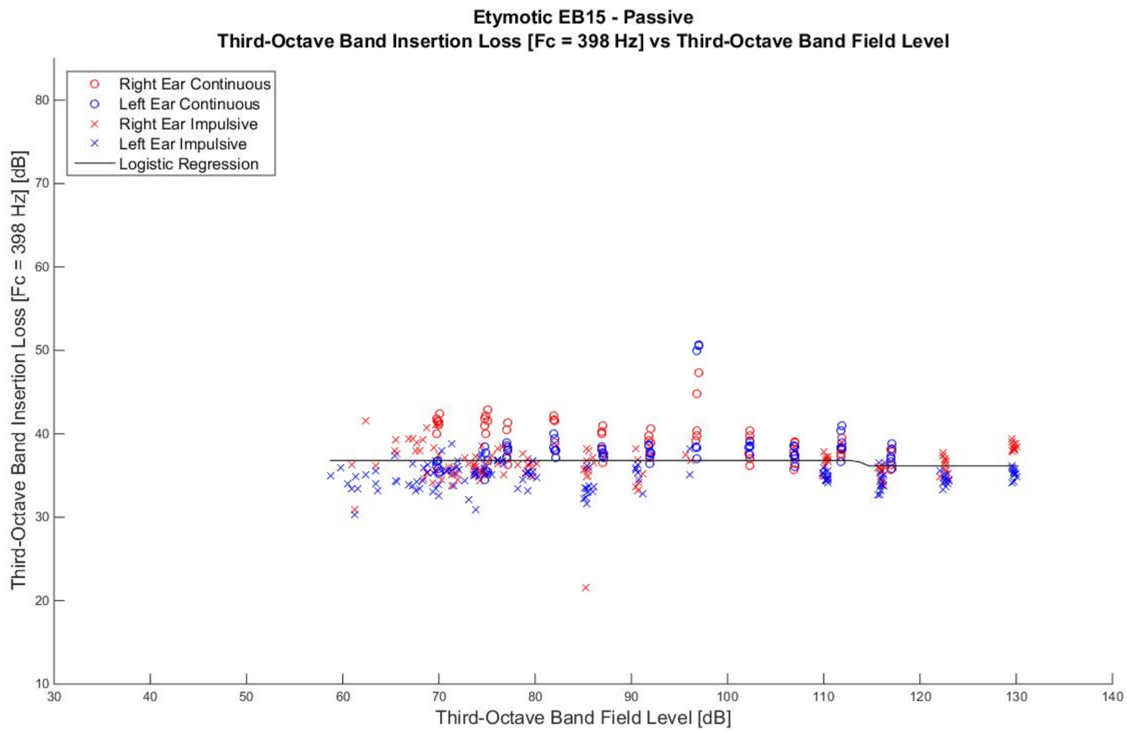

Figure A-76. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

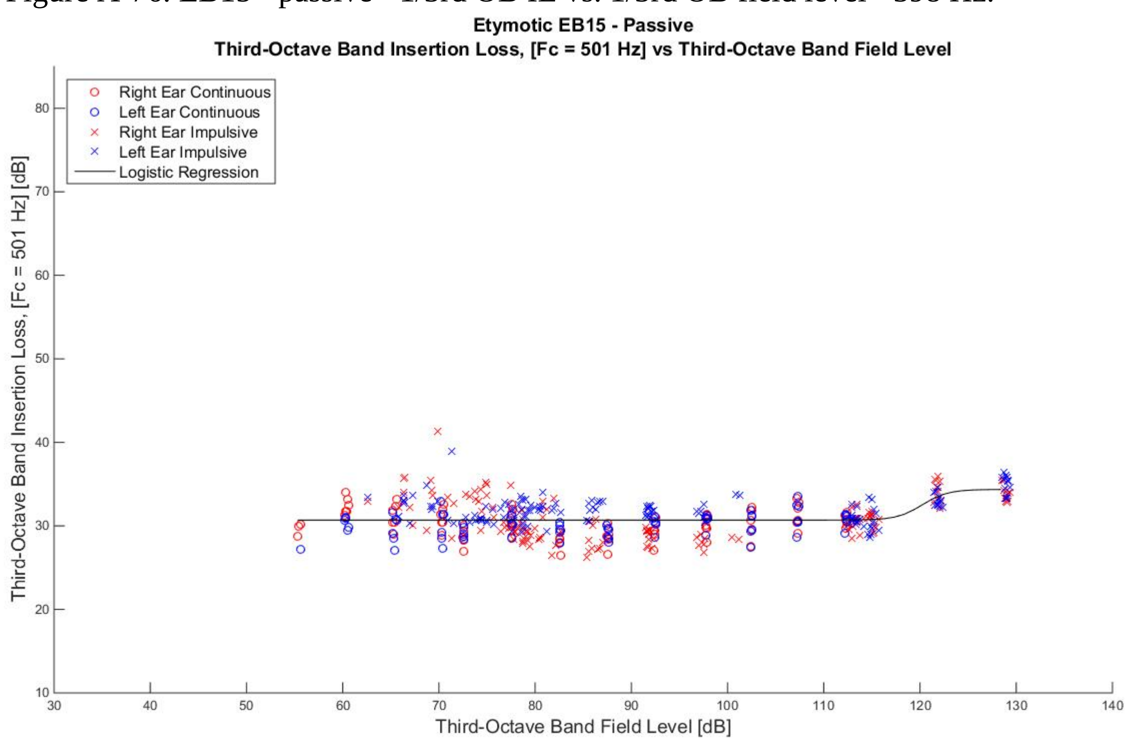

Figure A-77. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

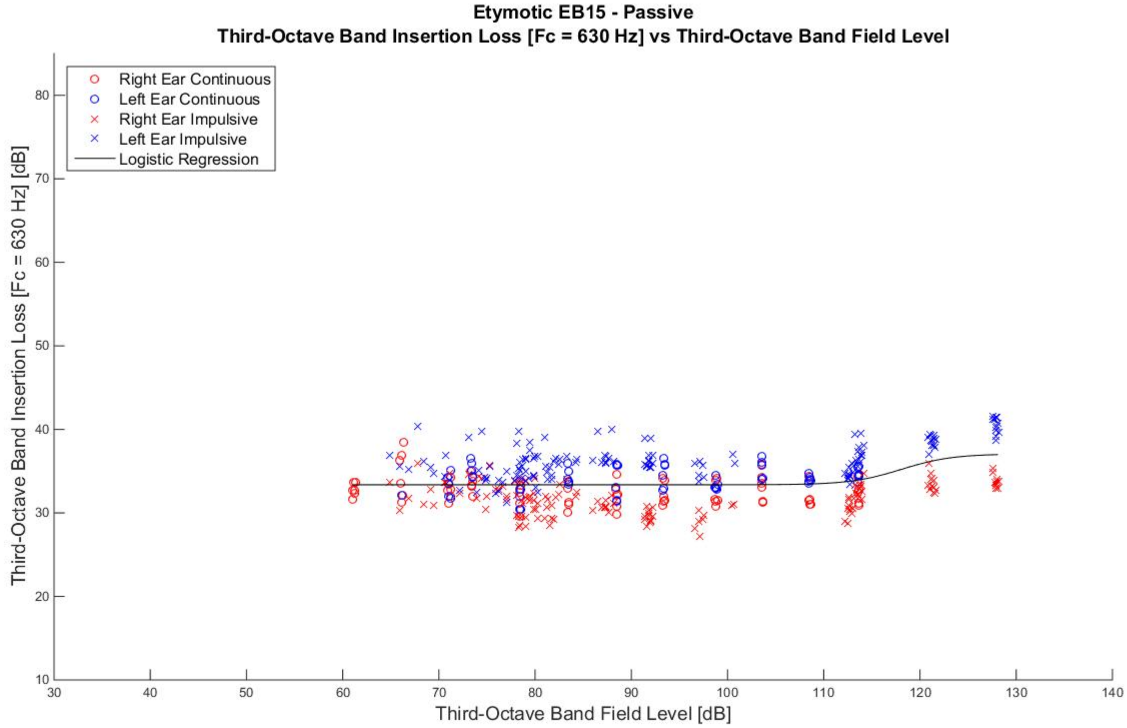

Figure A-78. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

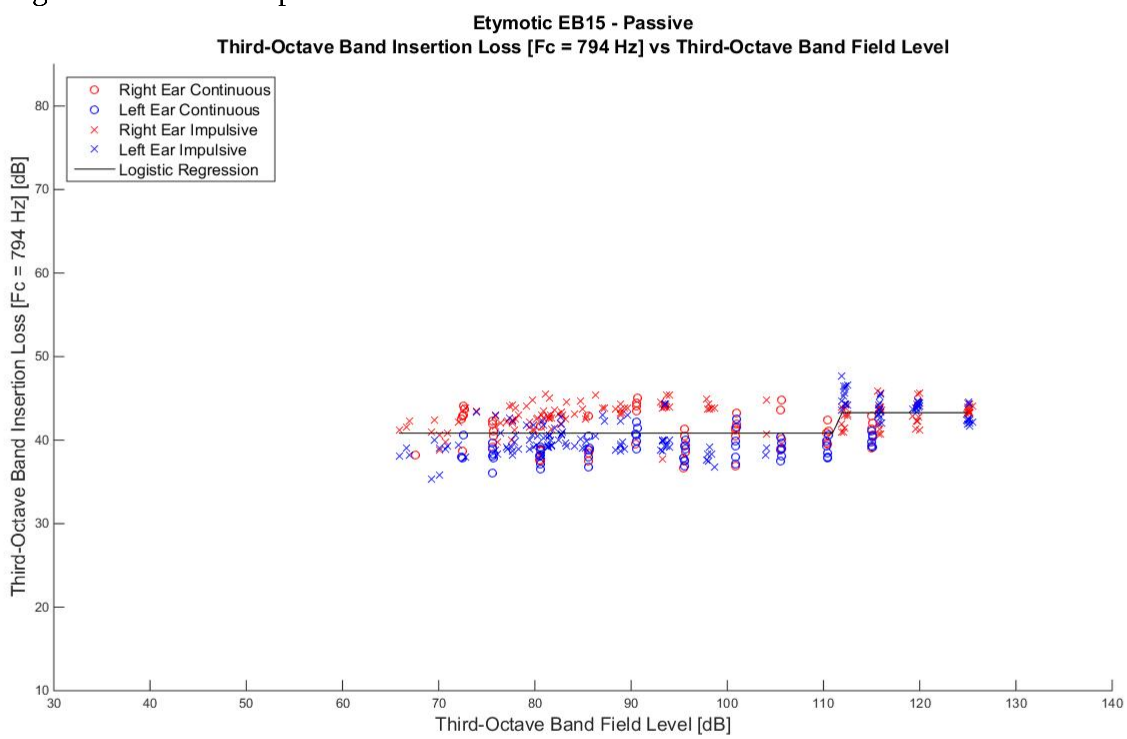

Figure A-79. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

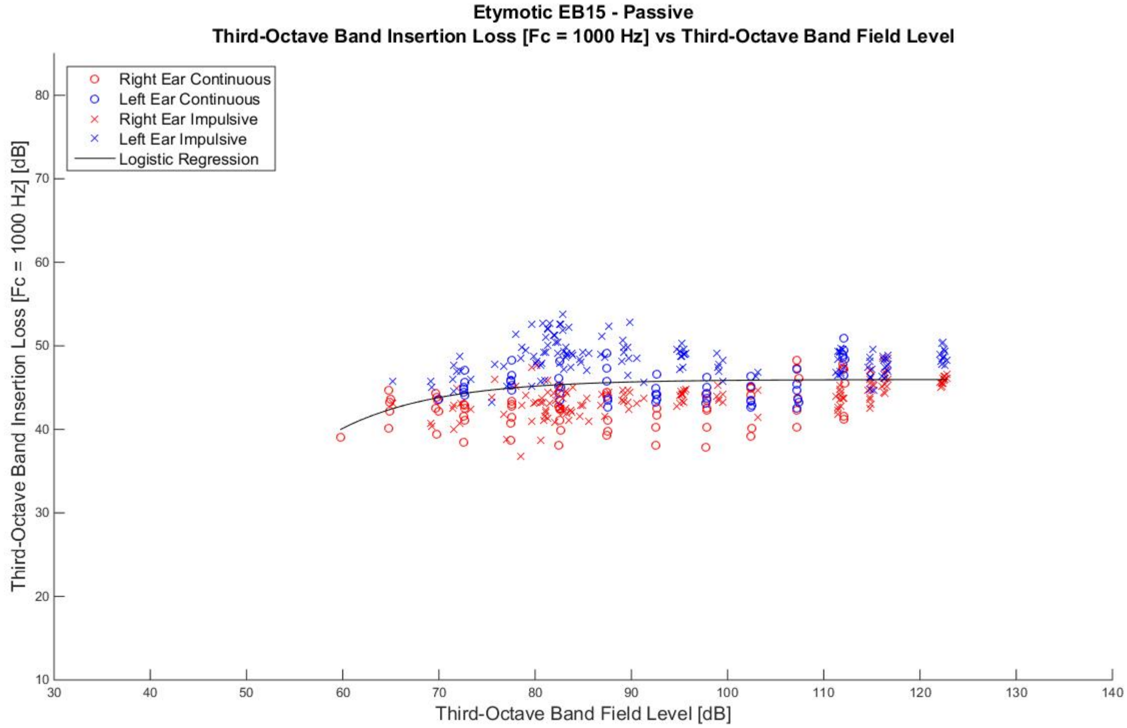

Figure A-80. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

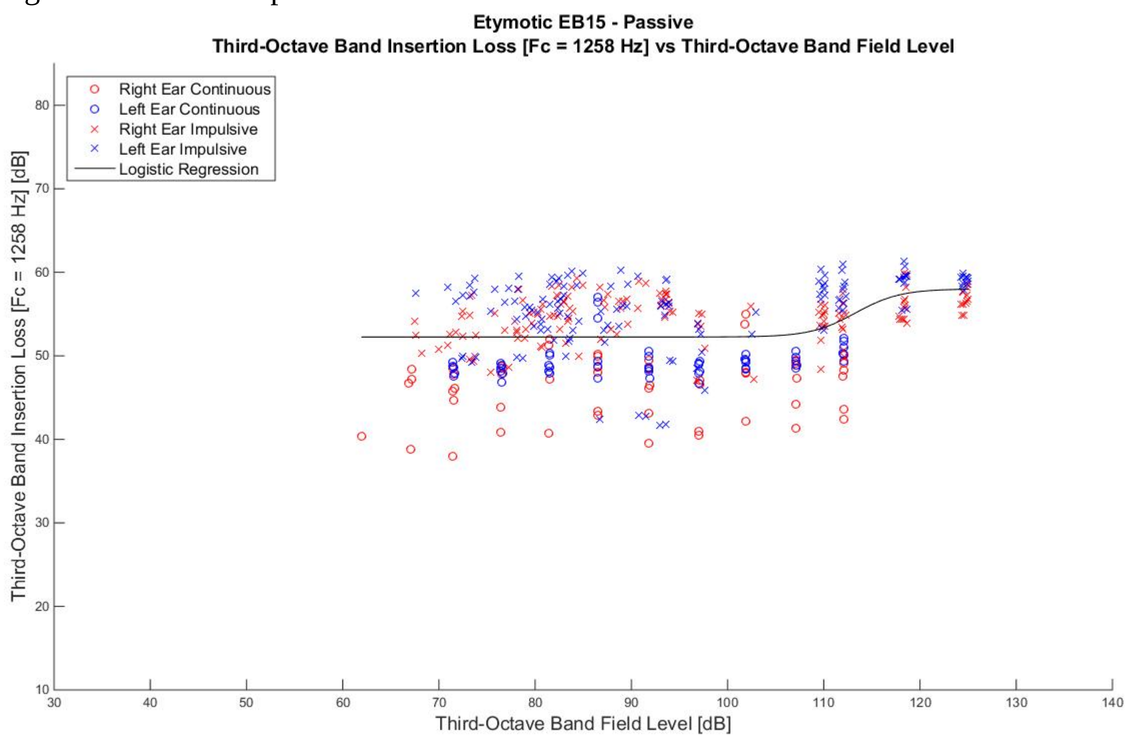

Figure A-81. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

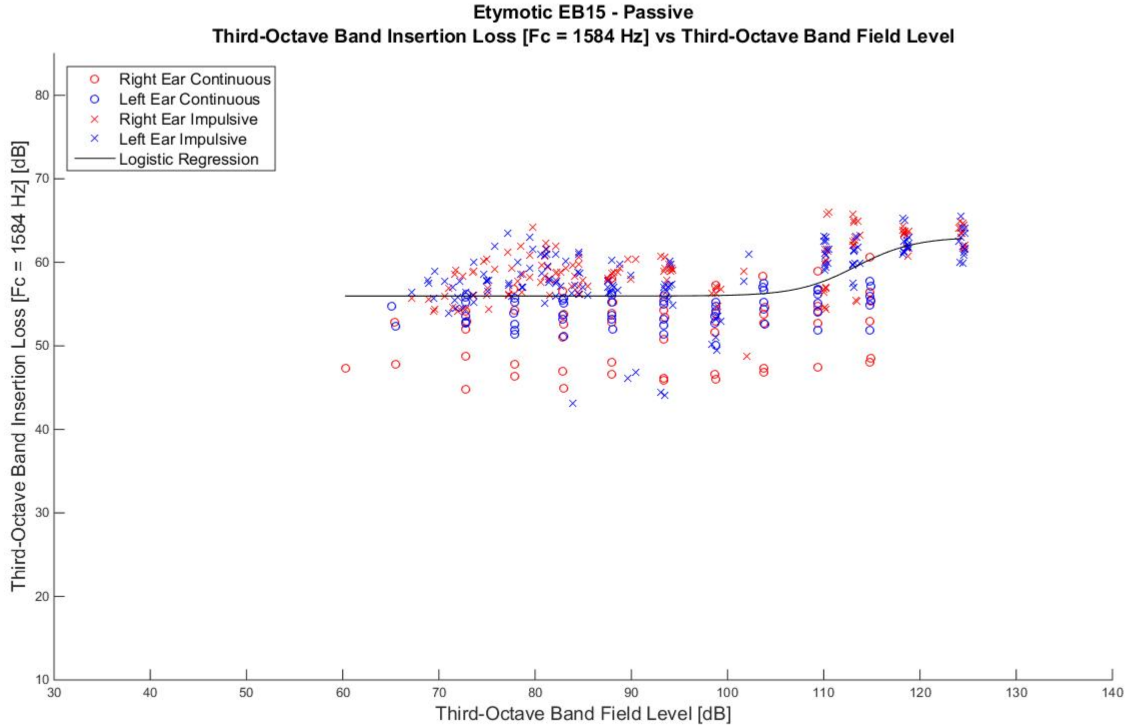

Figure A-82. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

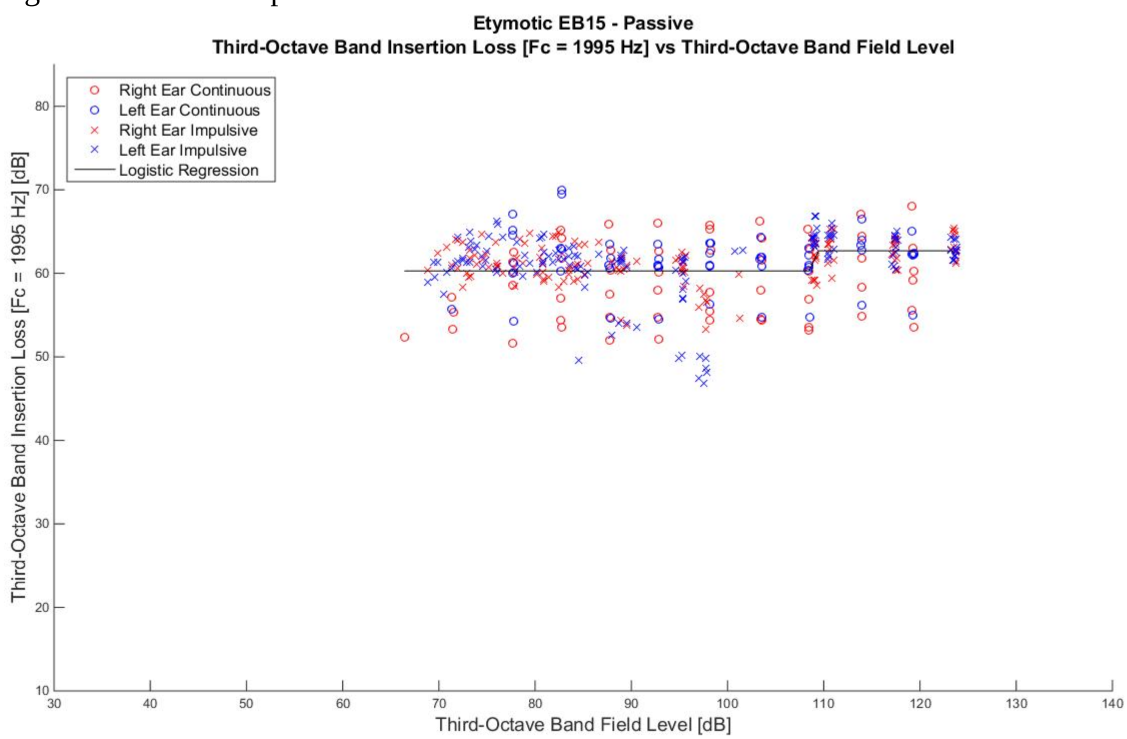

Figure A-83. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

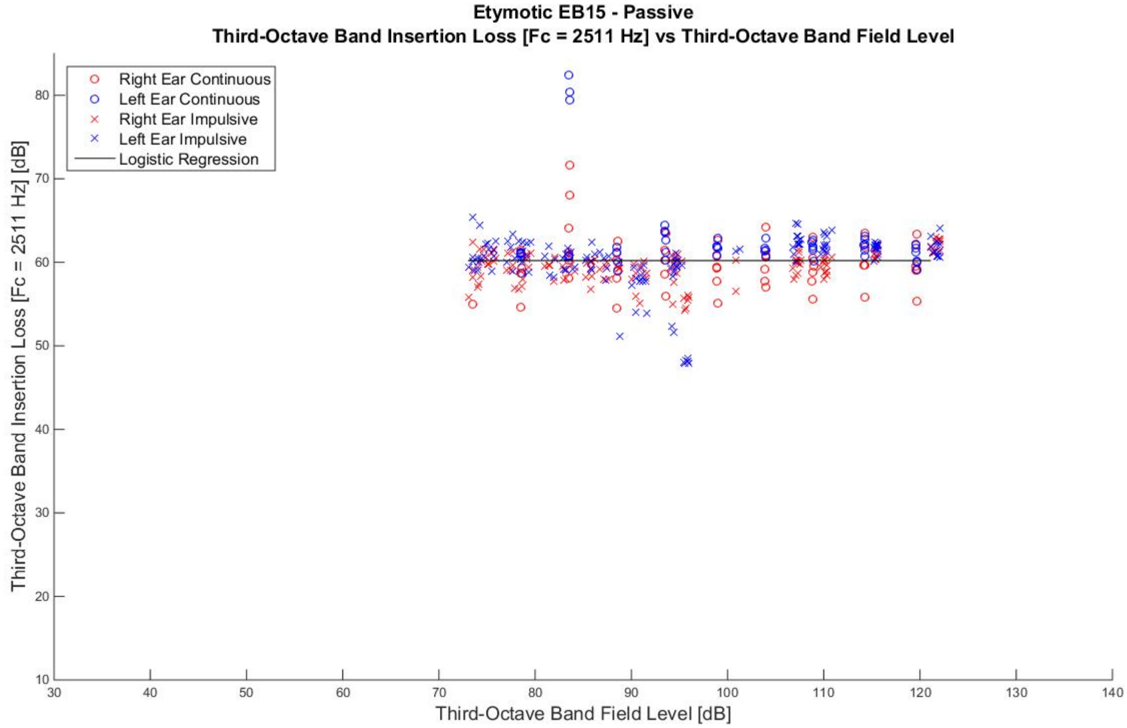

Figure A-84. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

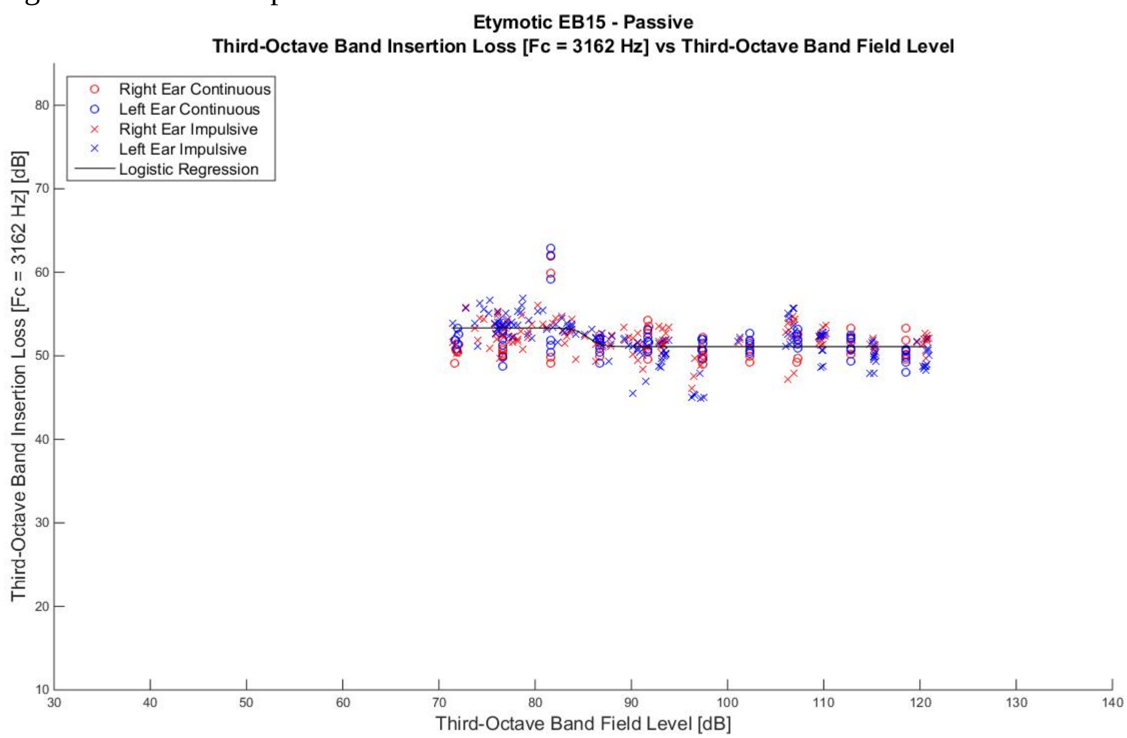

Figure A-85. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

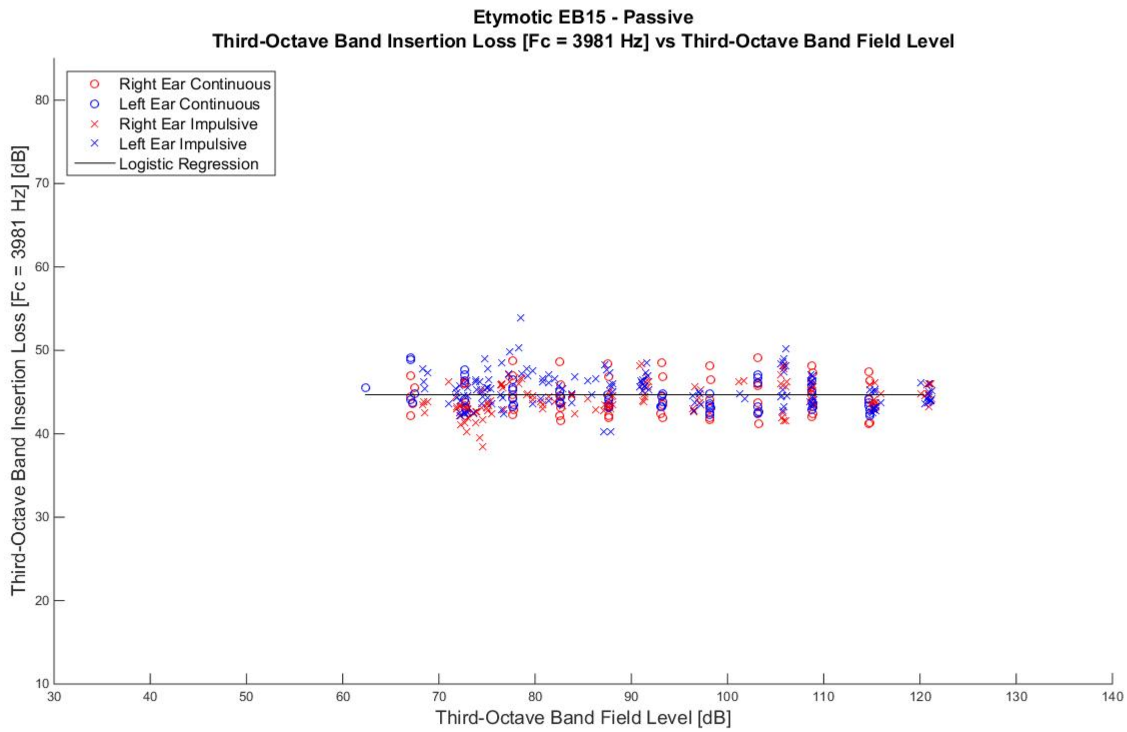

Figure A-86. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

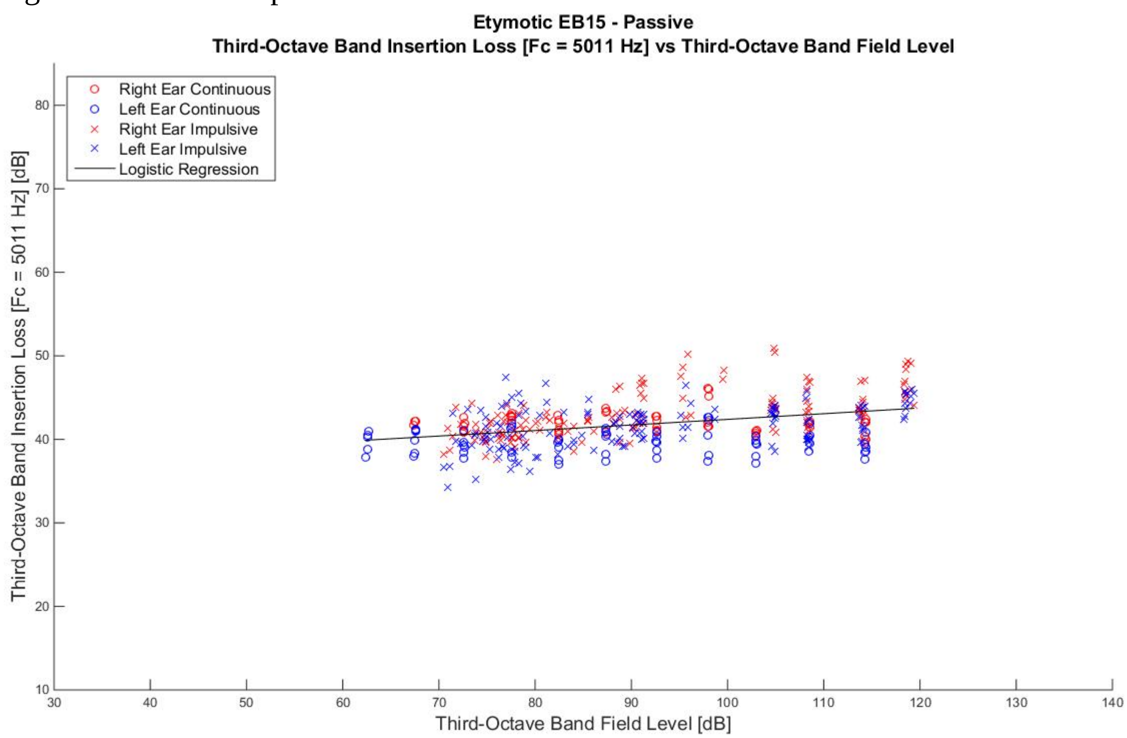

Figure A-87. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

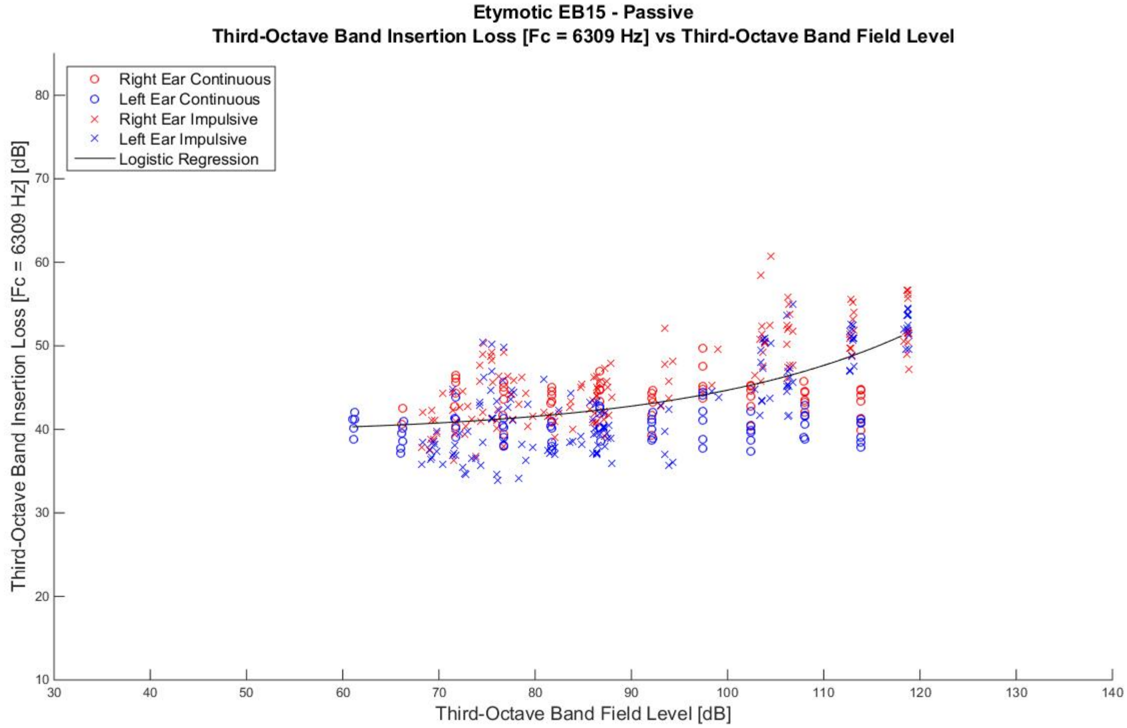

Figure A-88. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

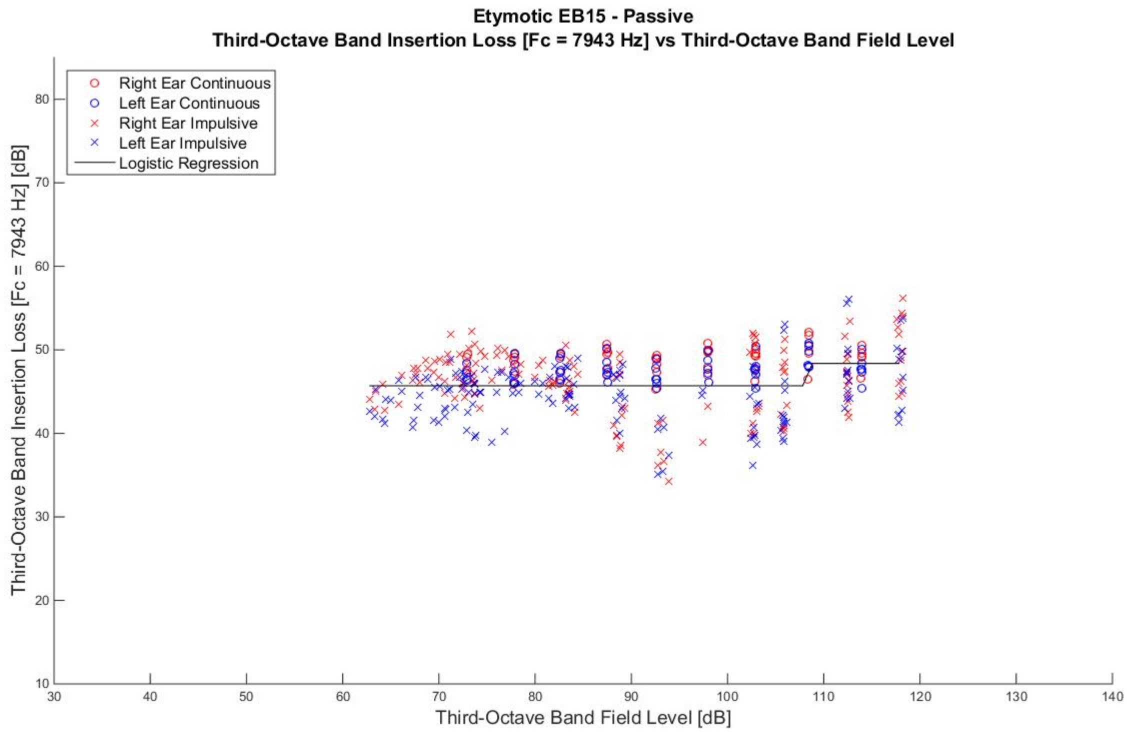

Figure A-89. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

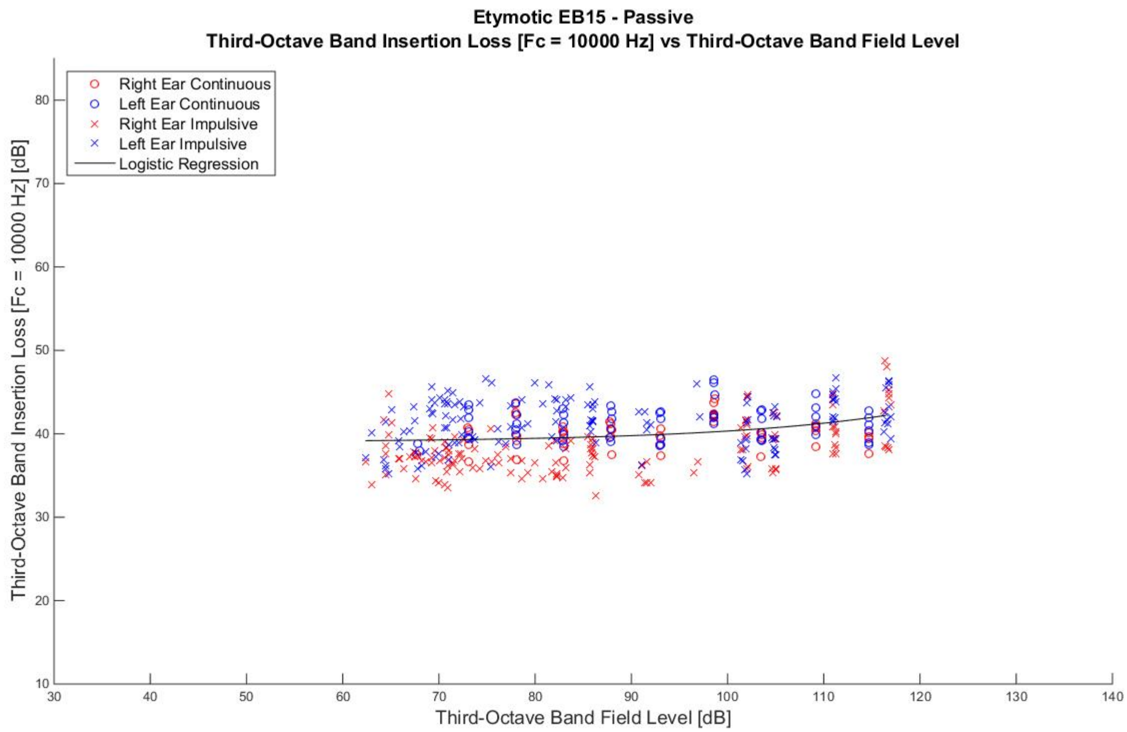

Figure A-90. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

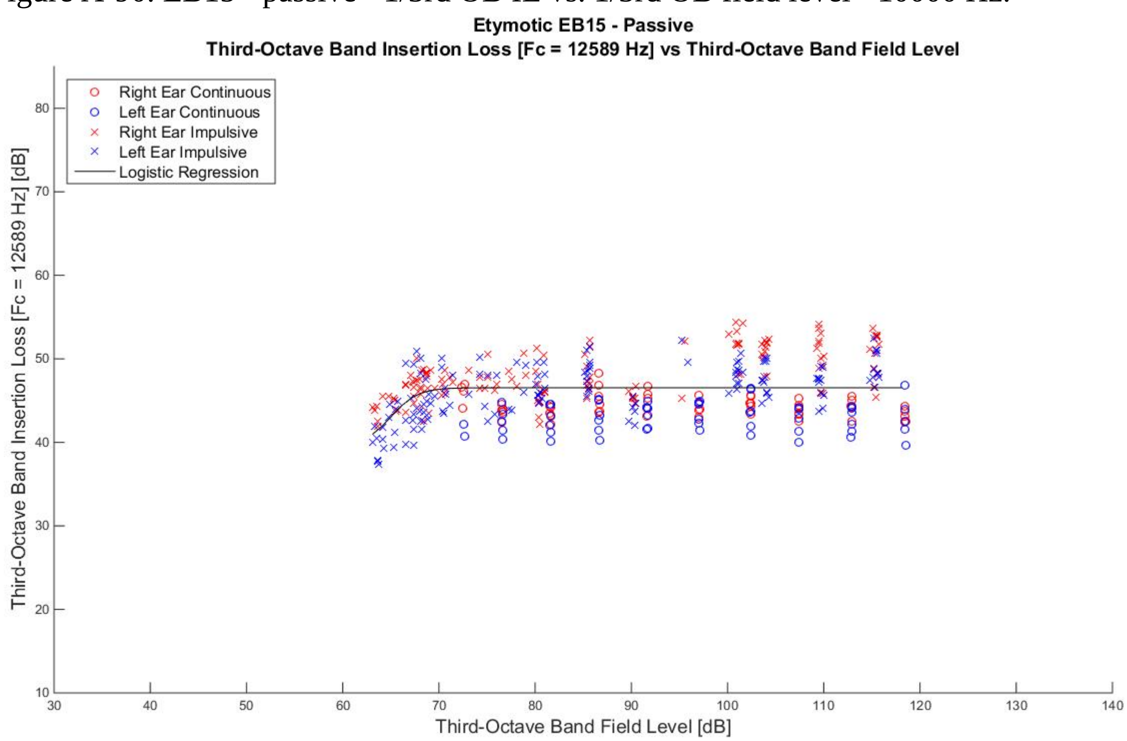

Figure A-91. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

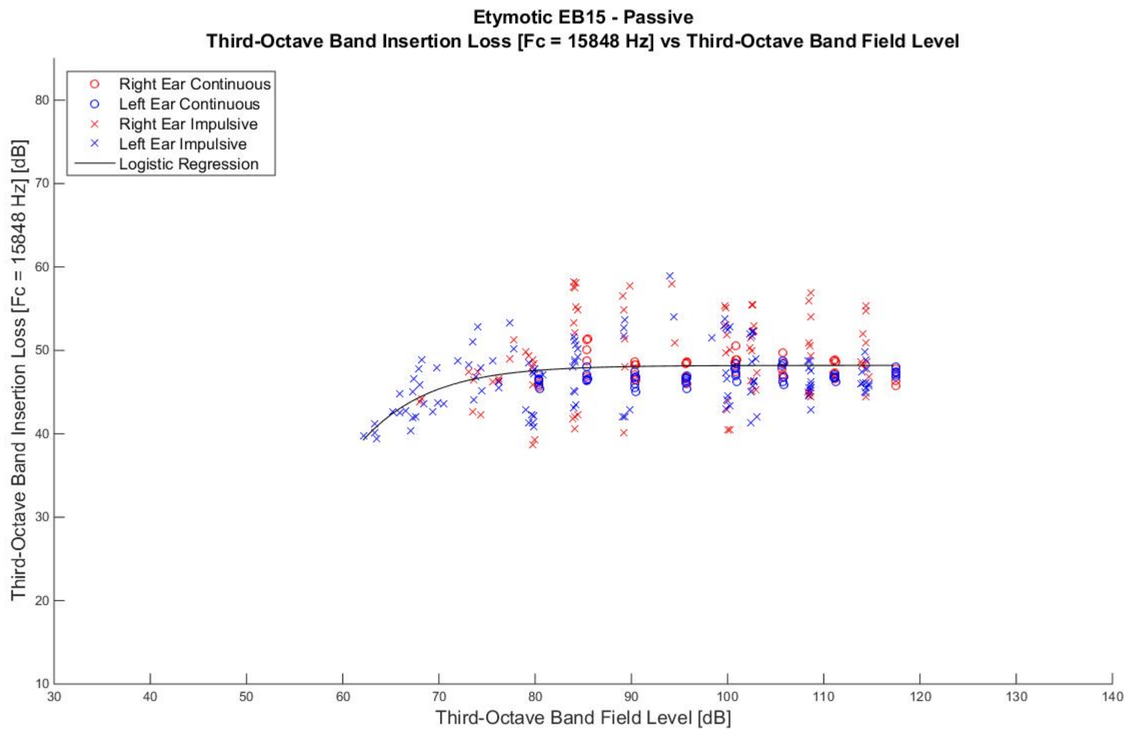

Figure A-92. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

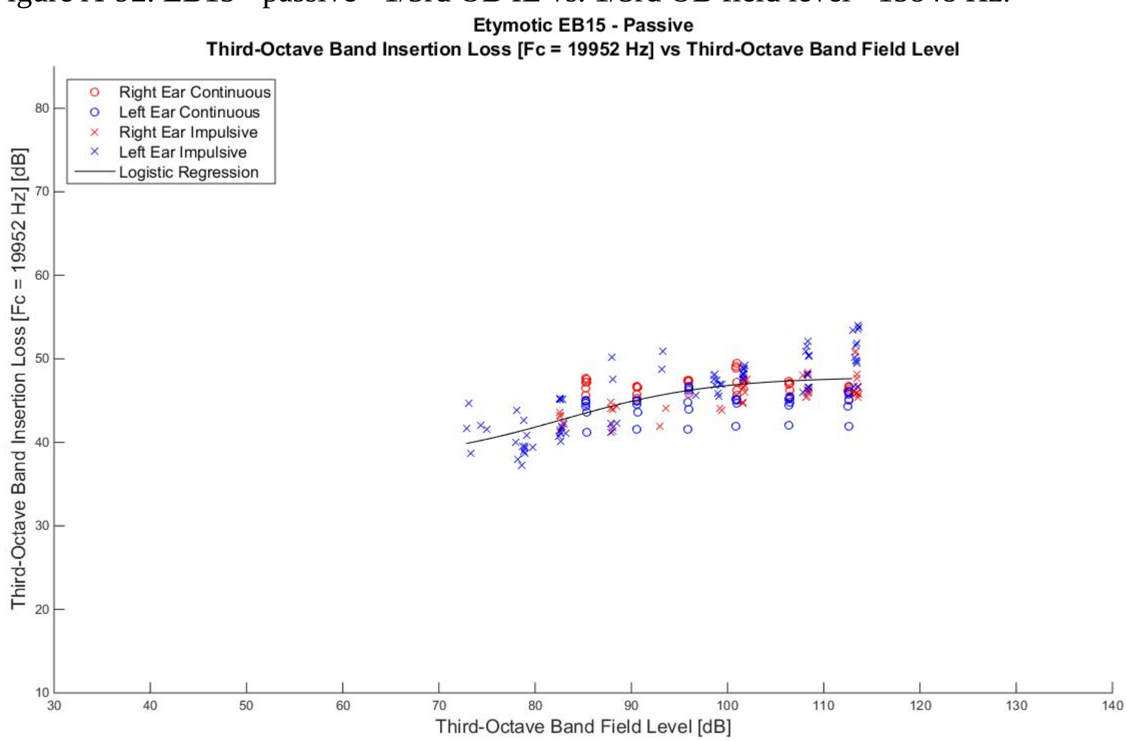

Figure A-93. EB15 - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

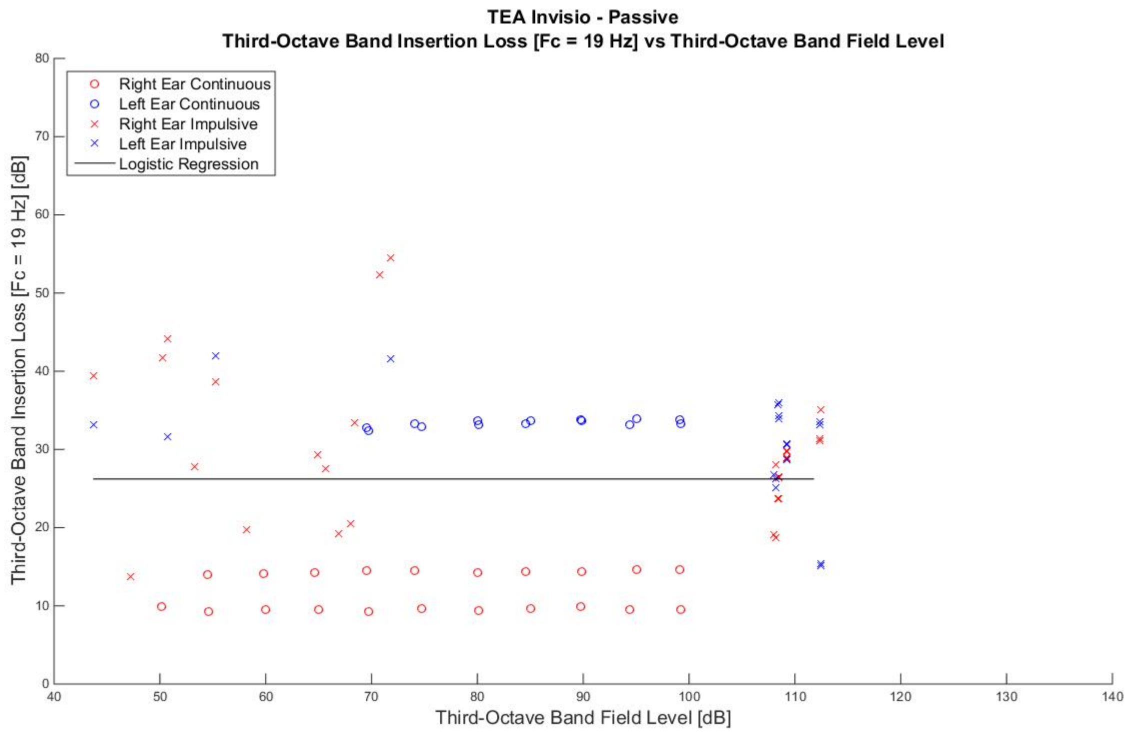

Figure A-94. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

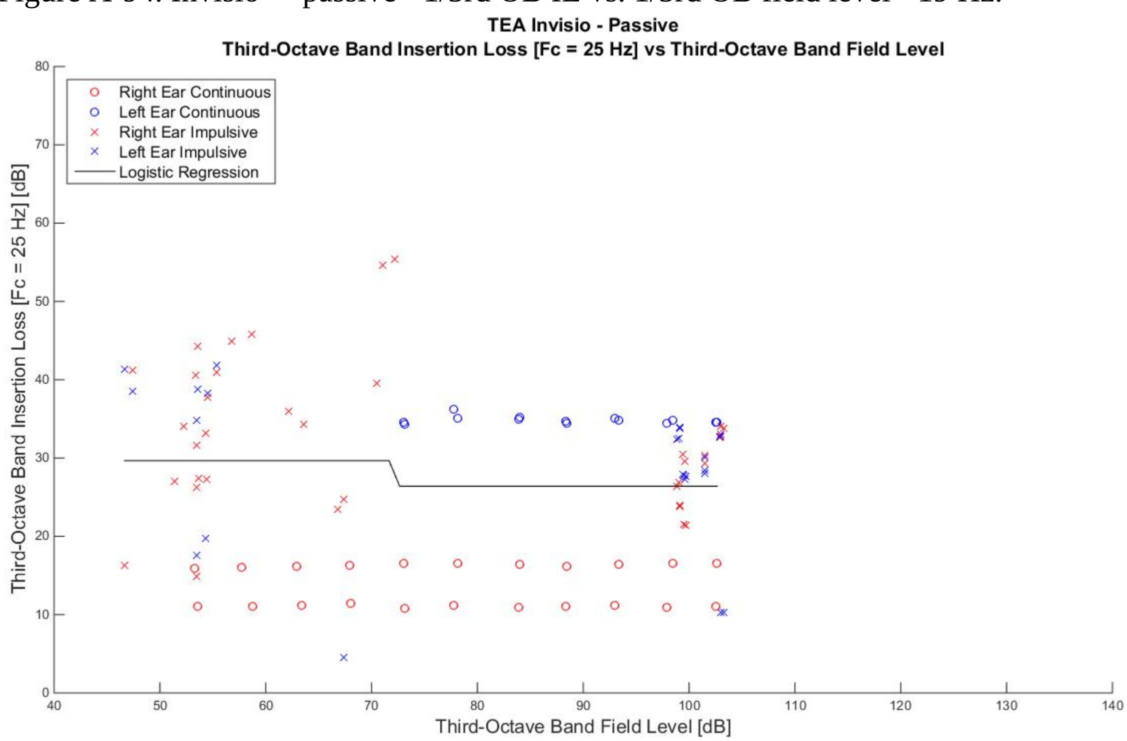

Figure A-95. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

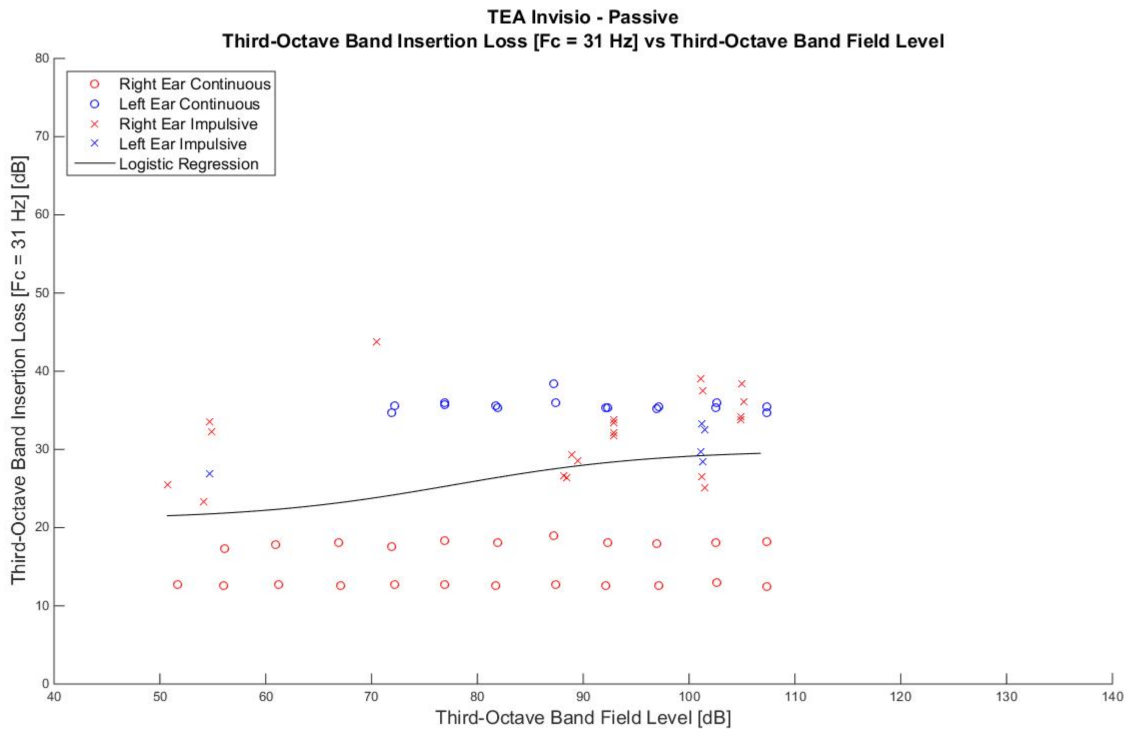

Figure A-96. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

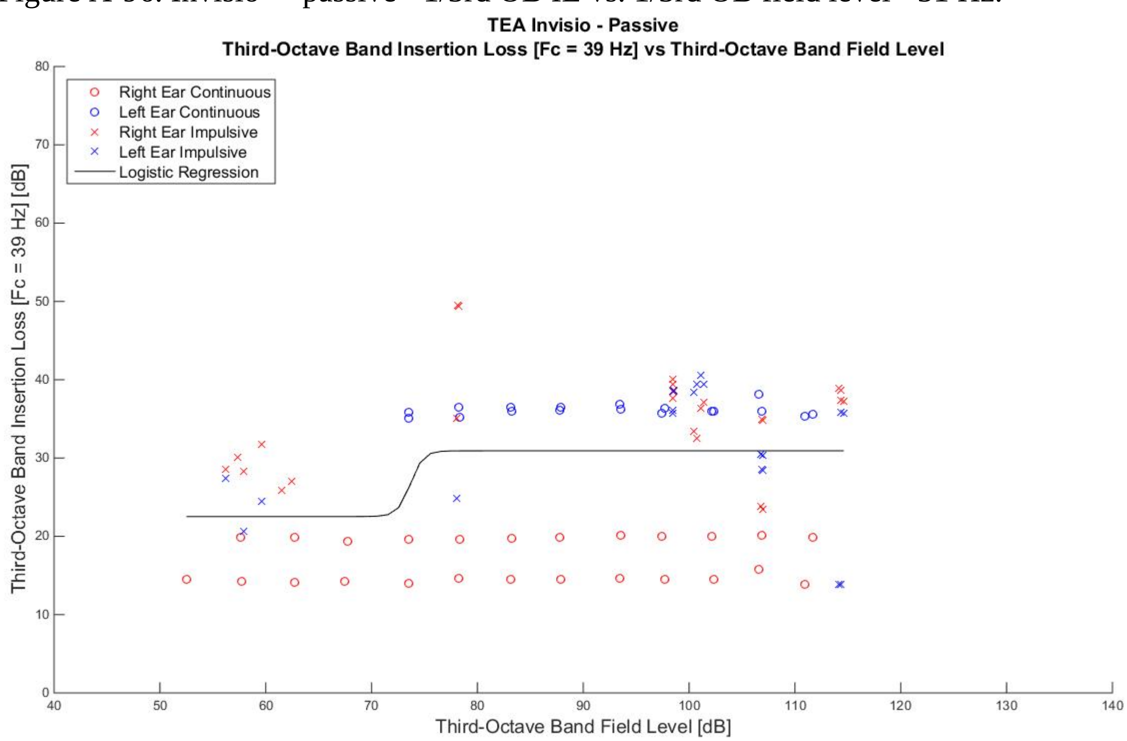

Figure A-97. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

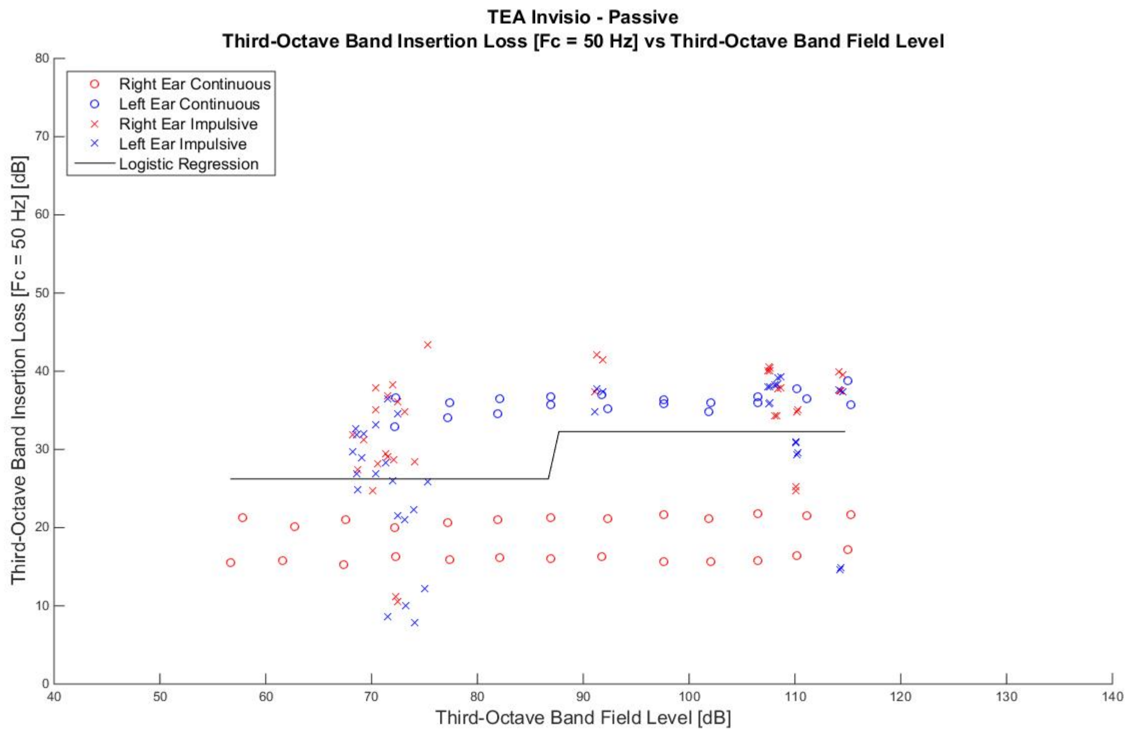

Figure A-98. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

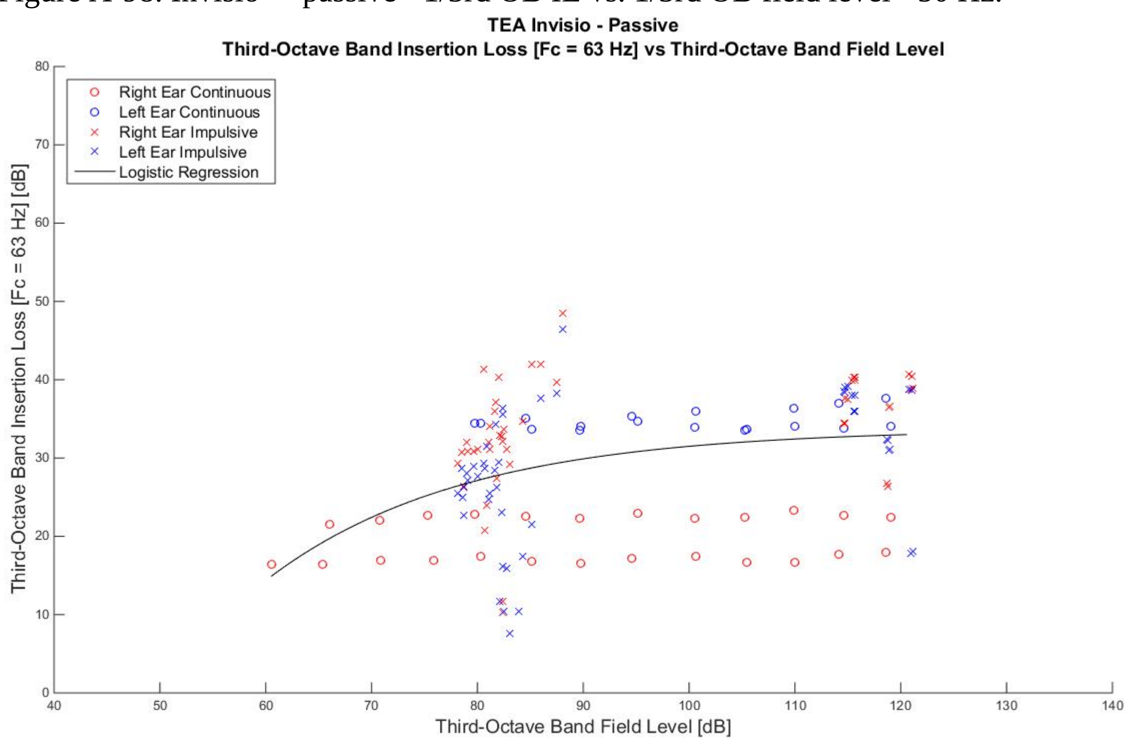

Figure A-99. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

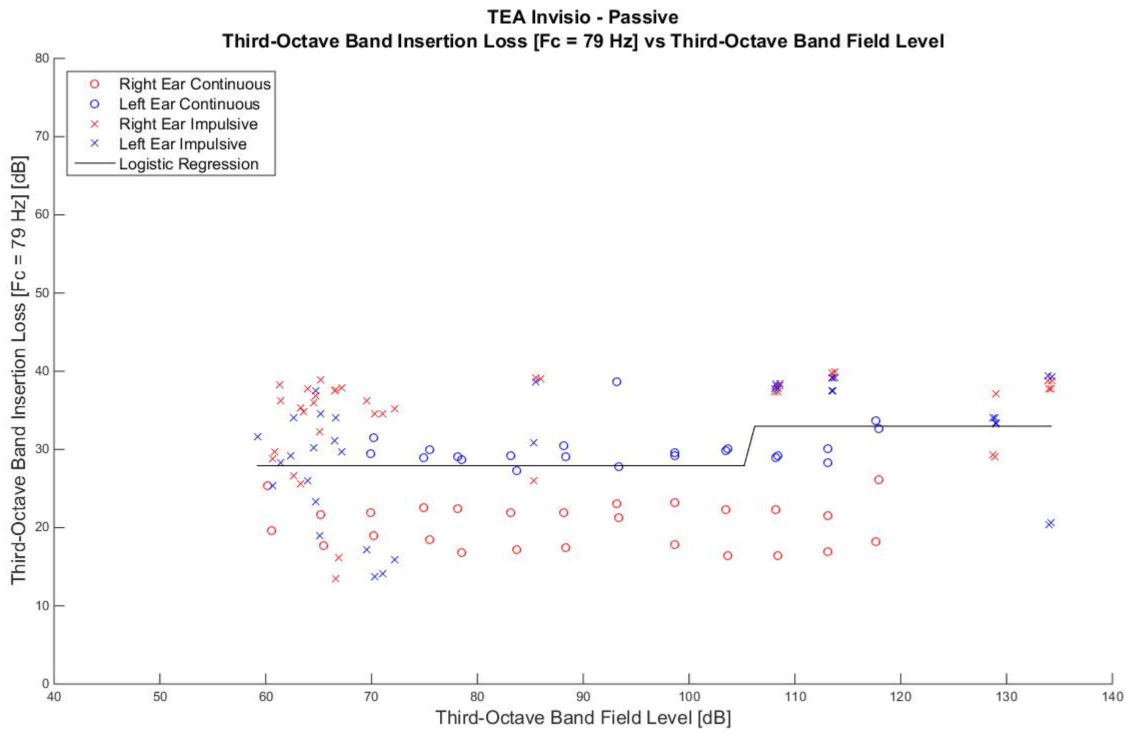

Figure A-100. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

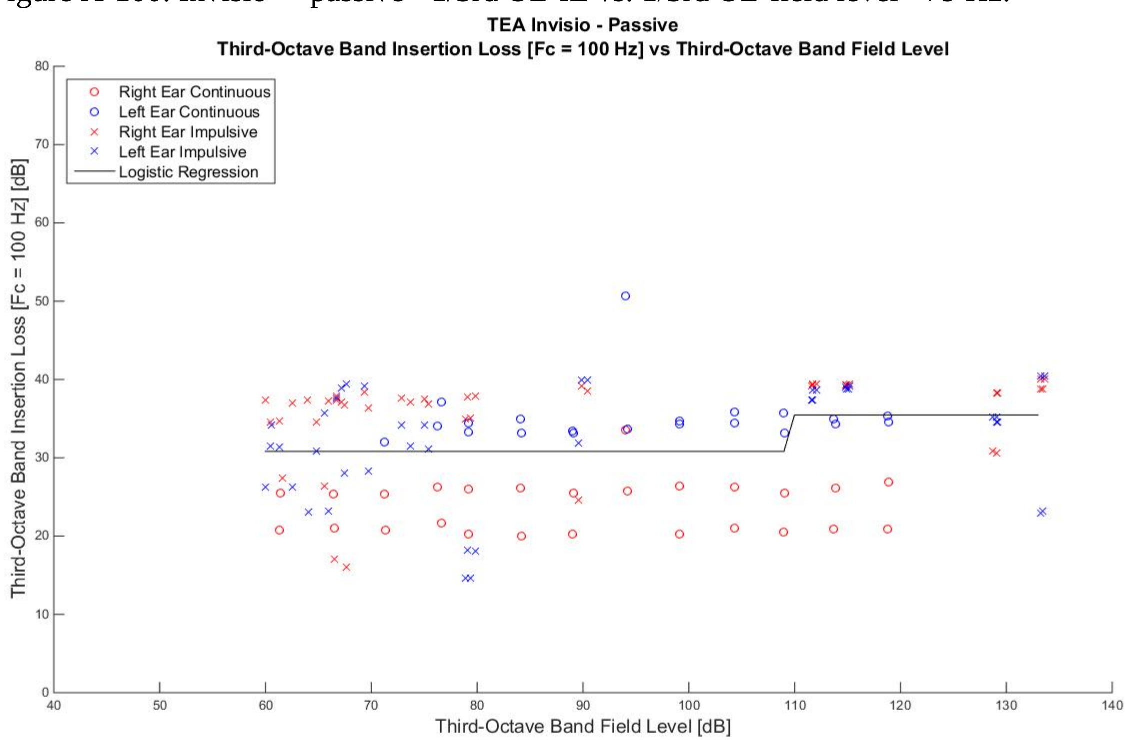

Figure A-101. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

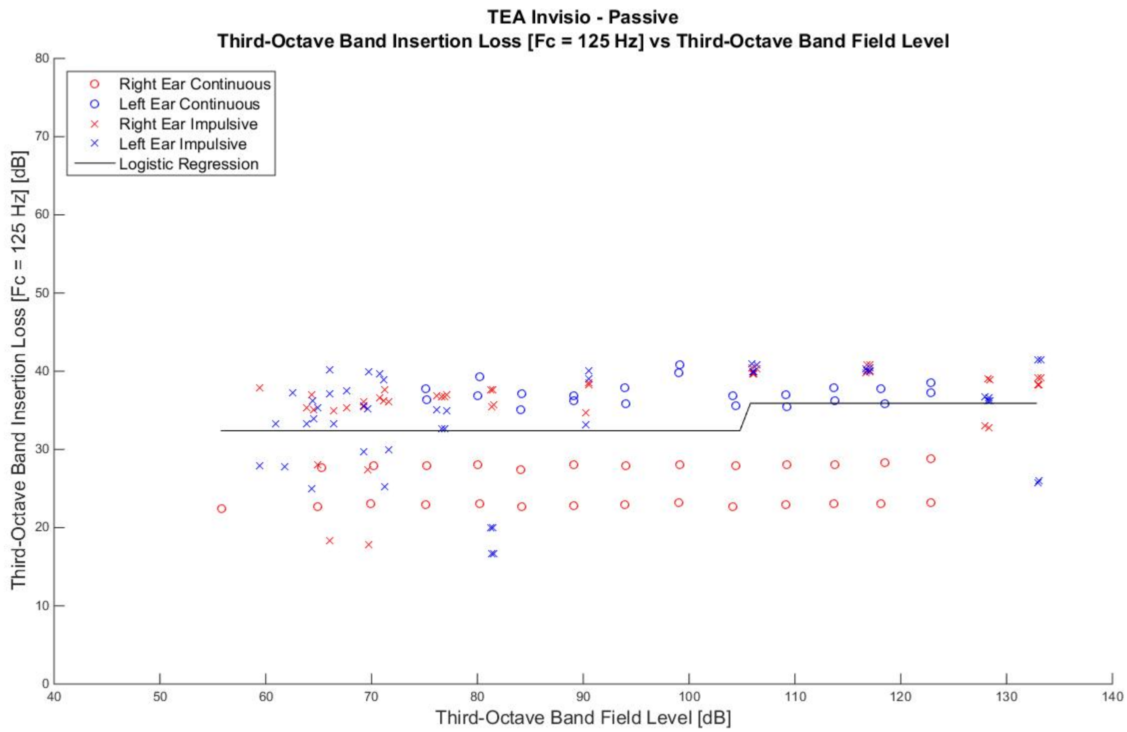

Figure A-102. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

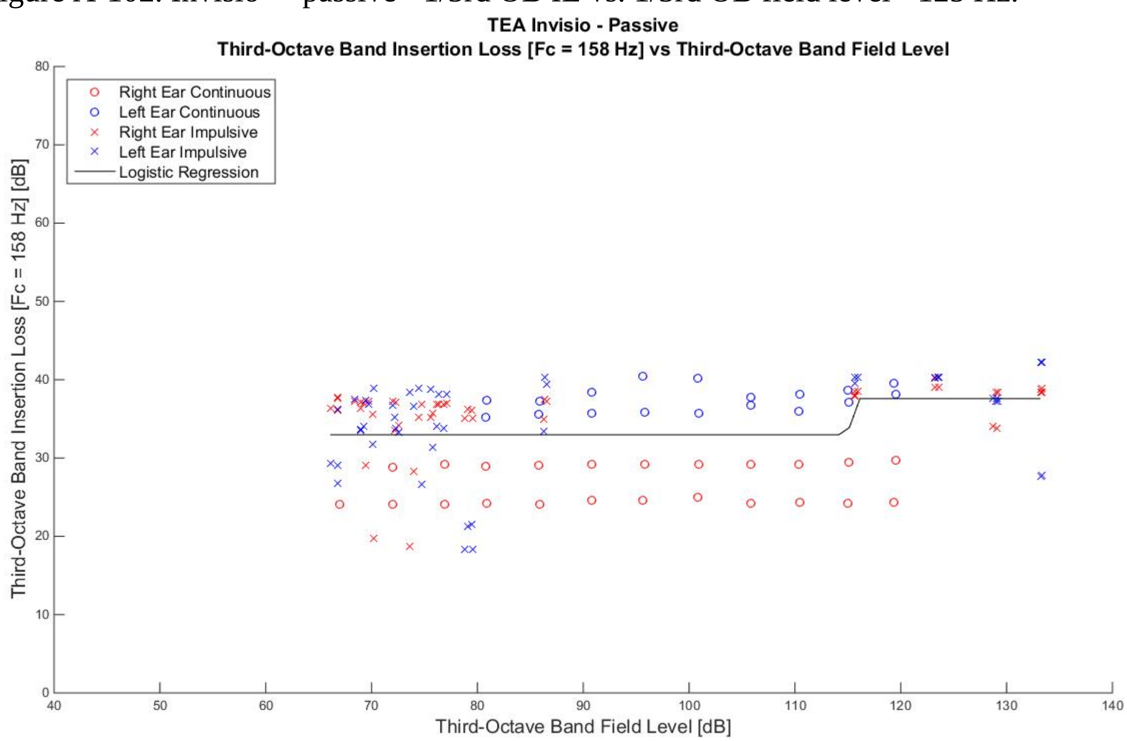

Figure A-103. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

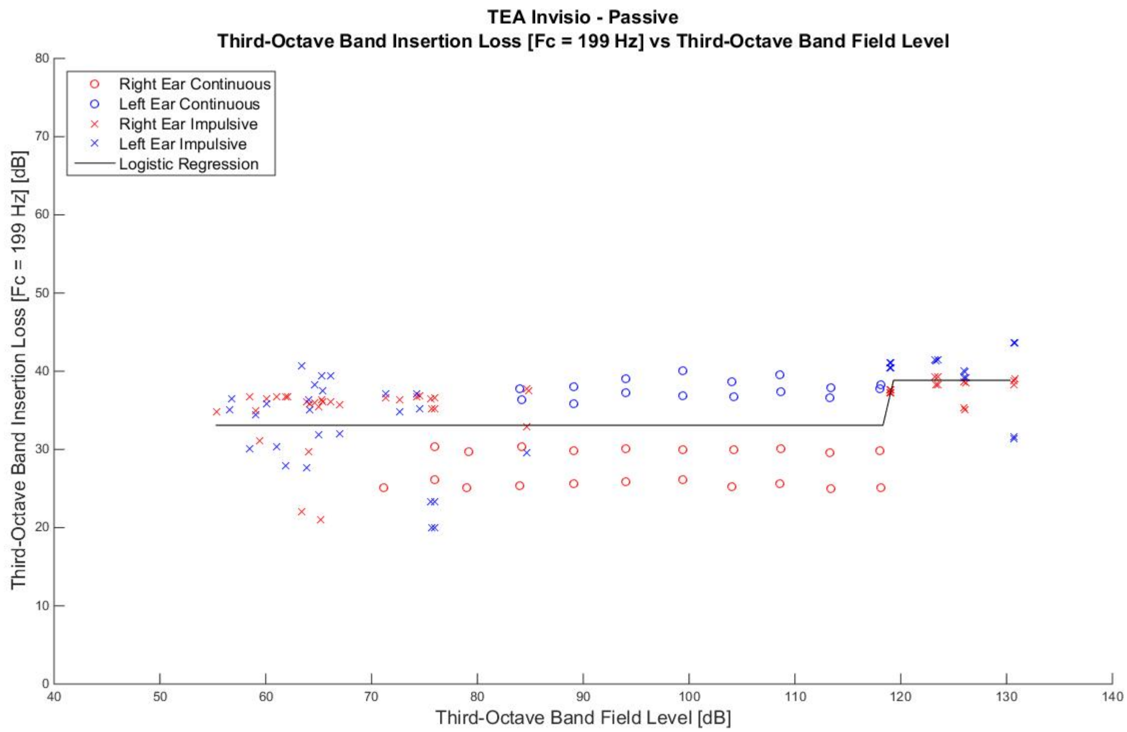

Figure A-104. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

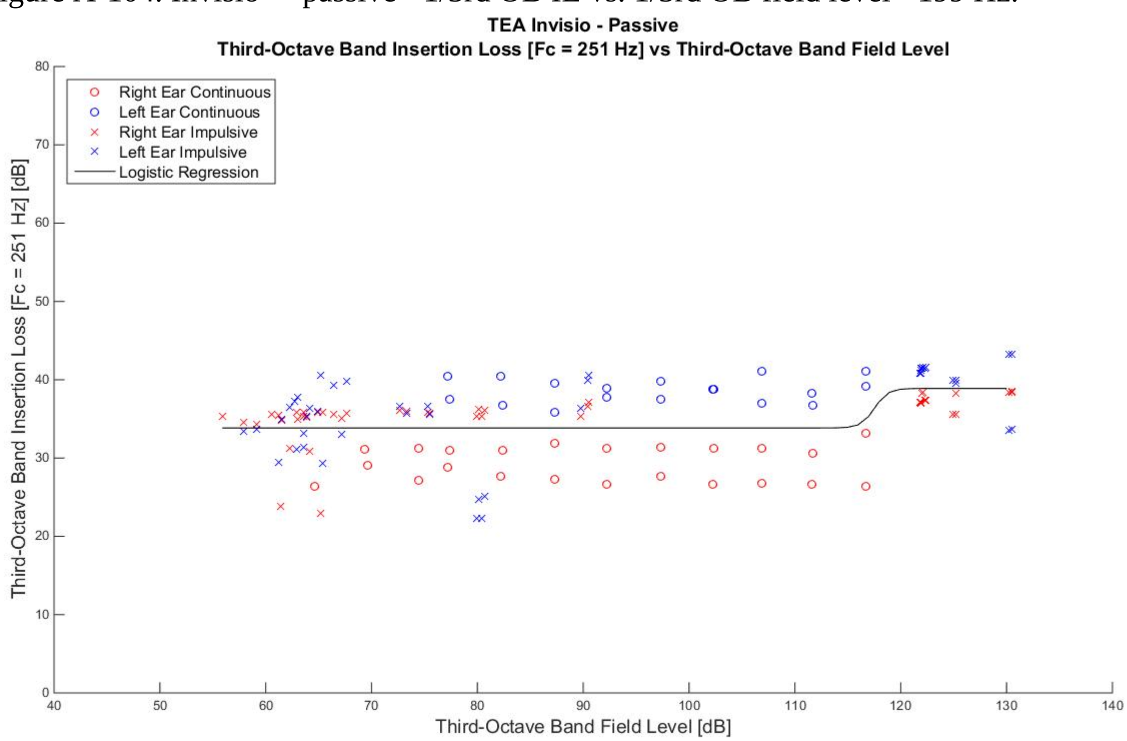

Figure A-105. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

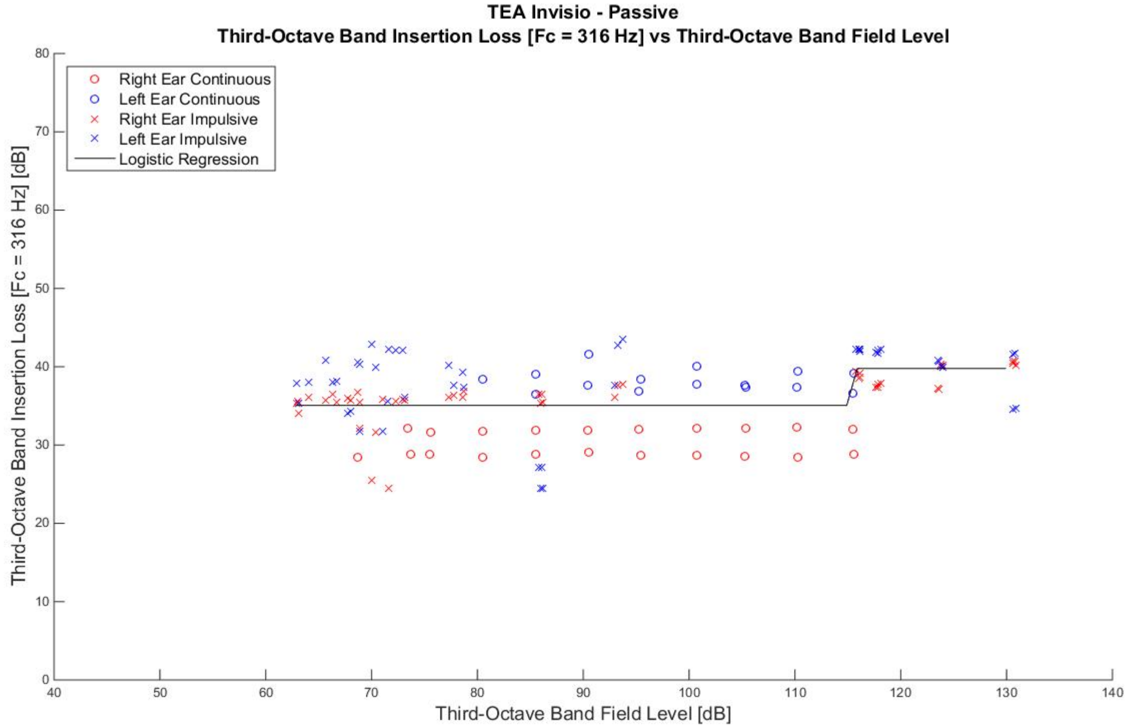

Figure A-106. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

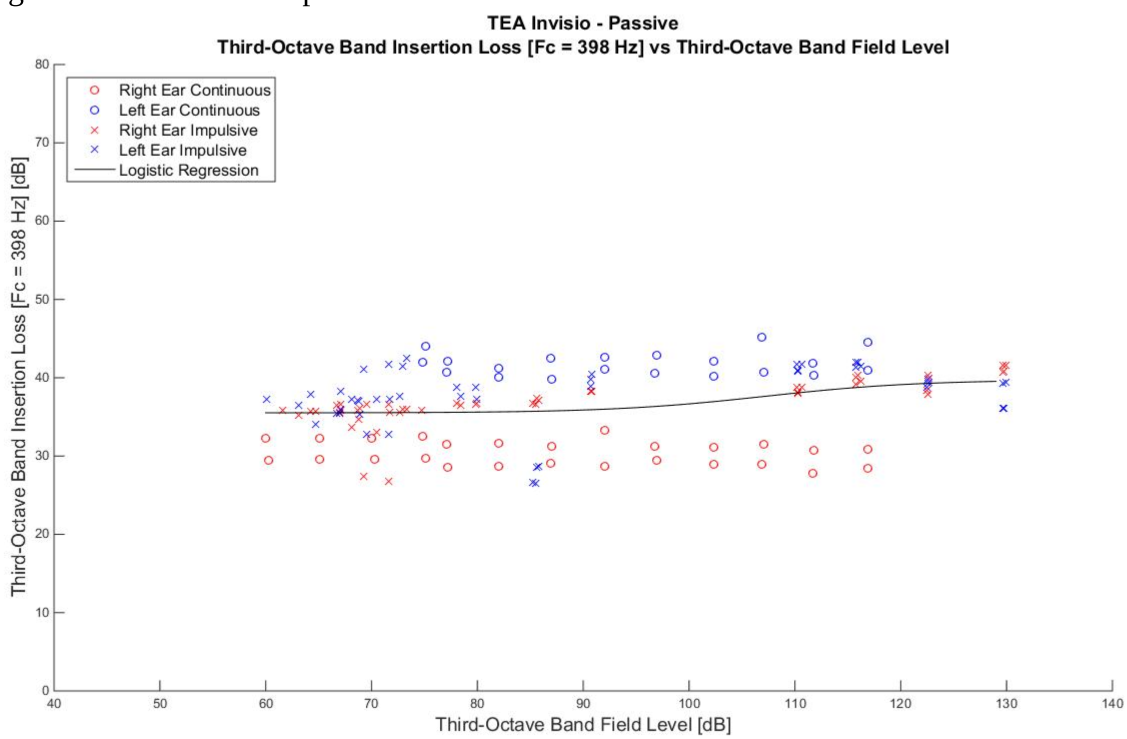

Figure A-107. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

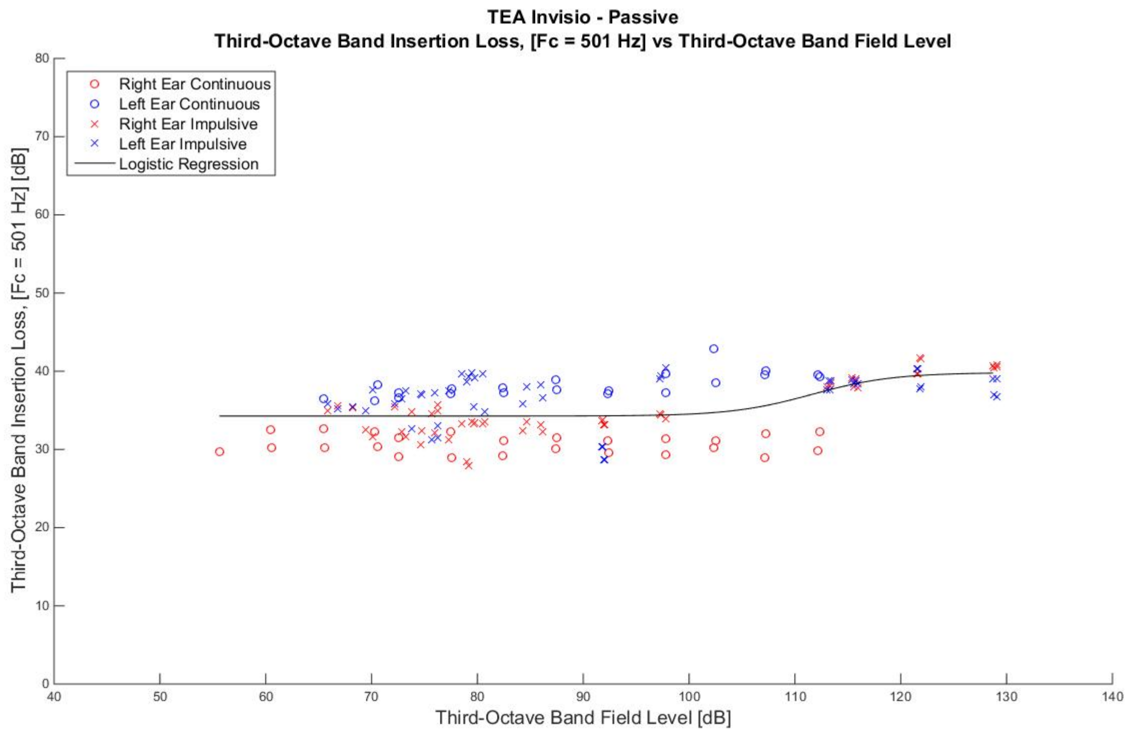

Figure A-108. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

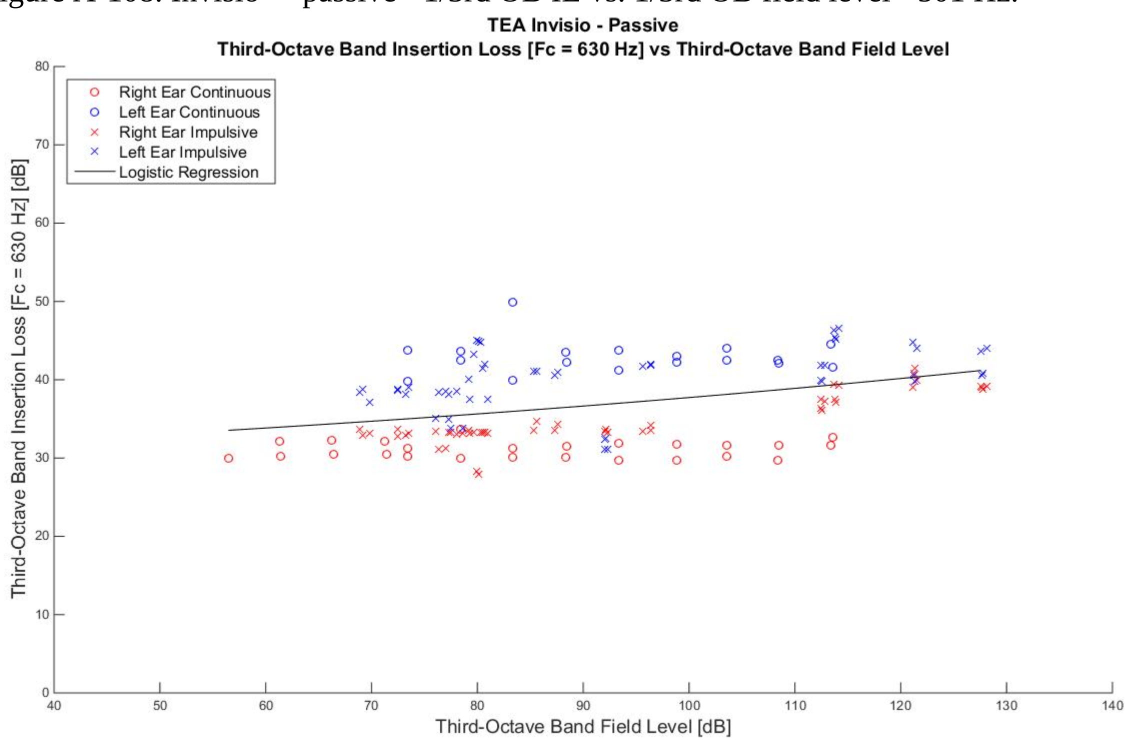

Figure A-109. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

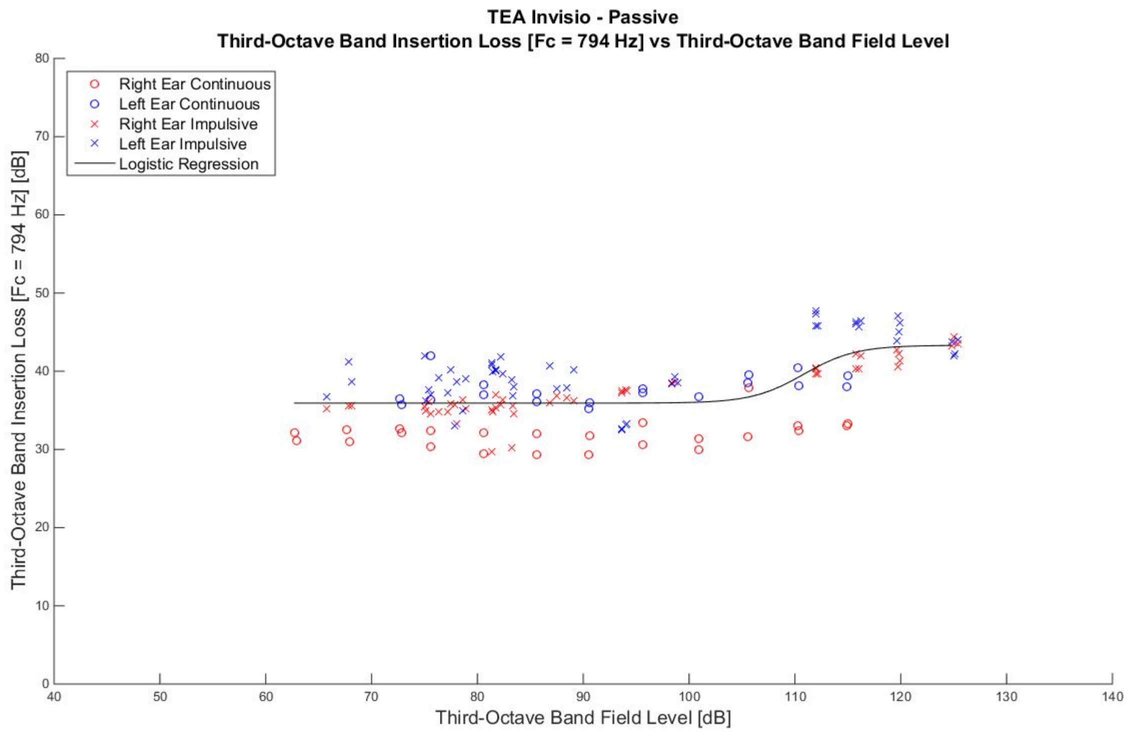

Figure A-110. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

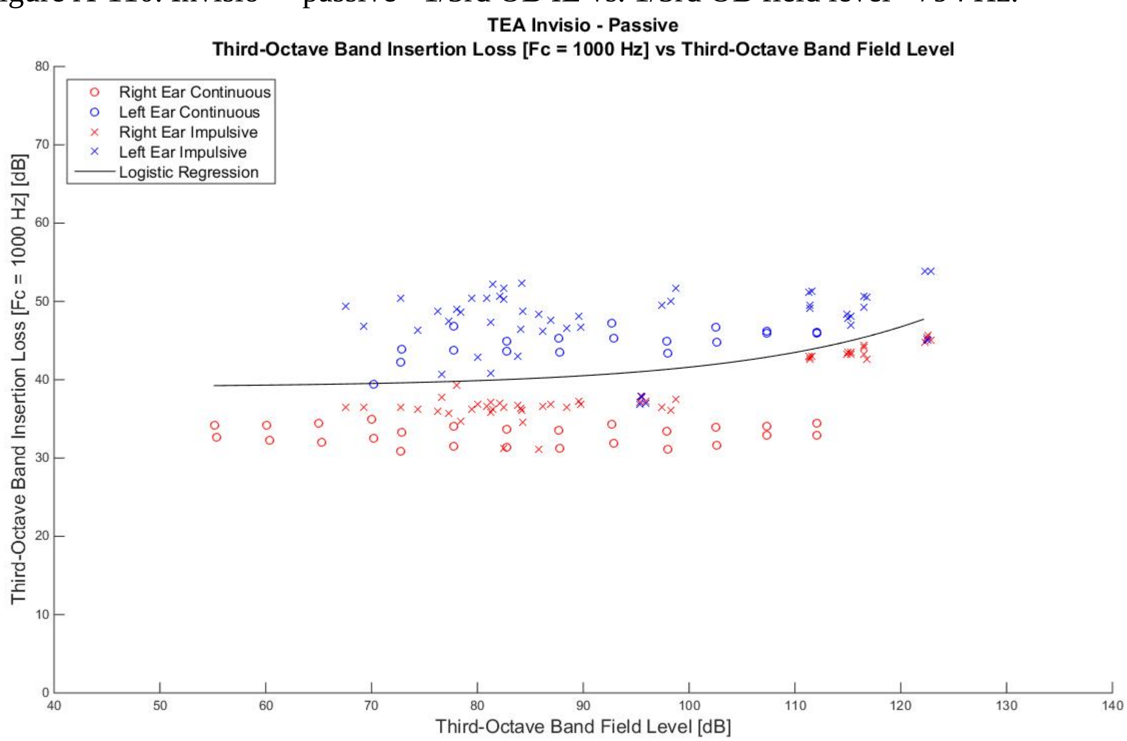

Figure A-111. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

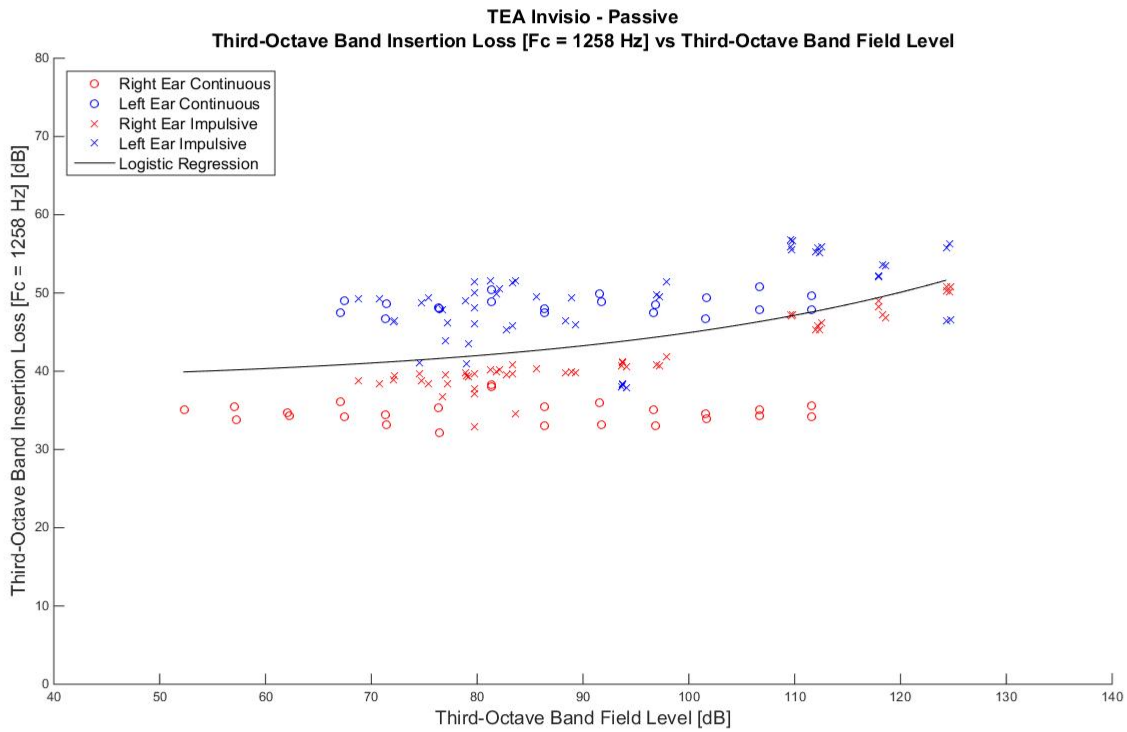

Figure A-112. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

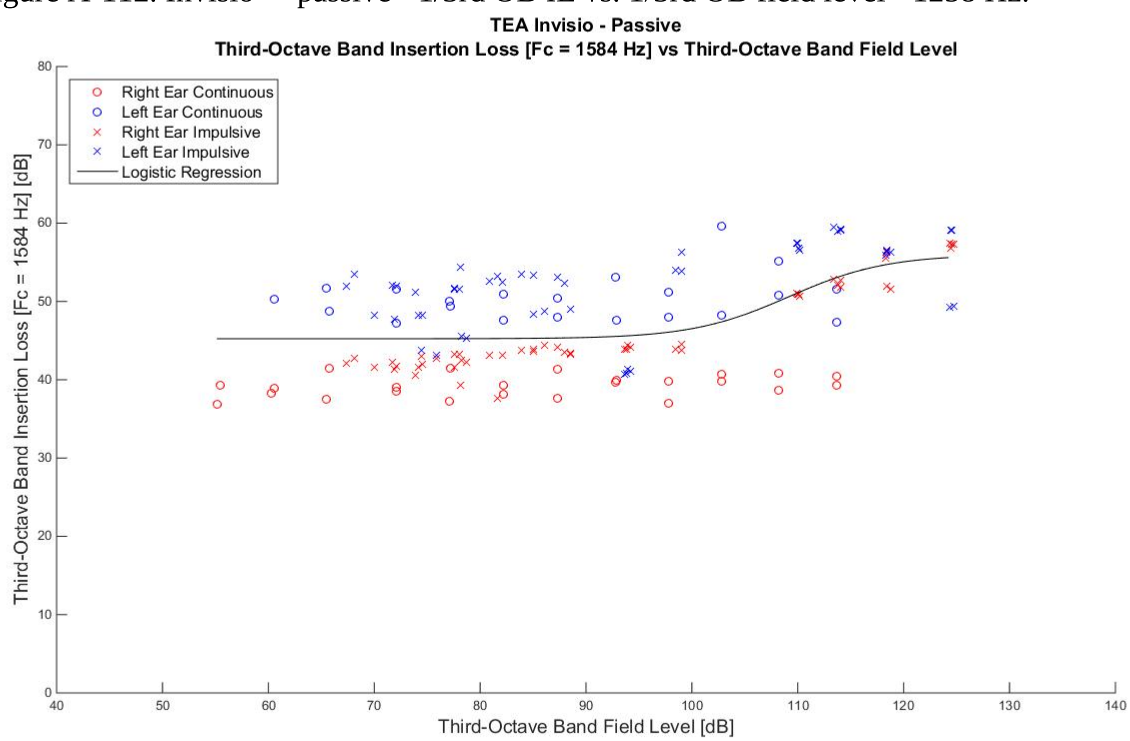

Figure A-113. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

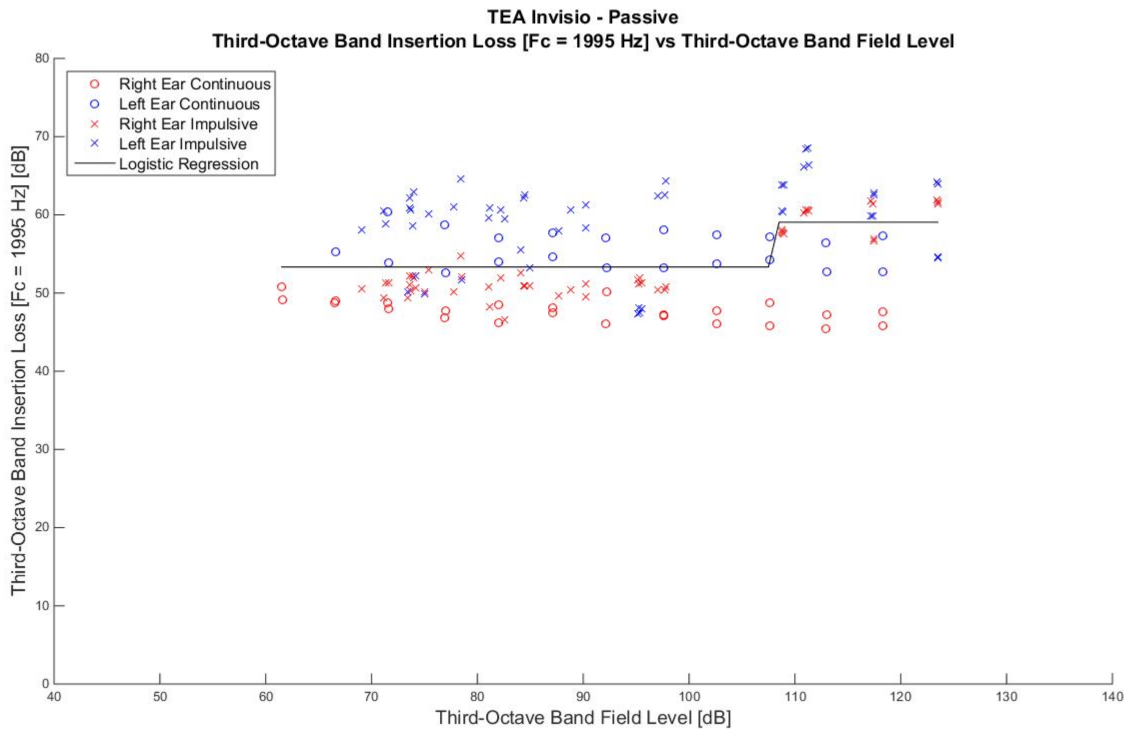

Figure A-114. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

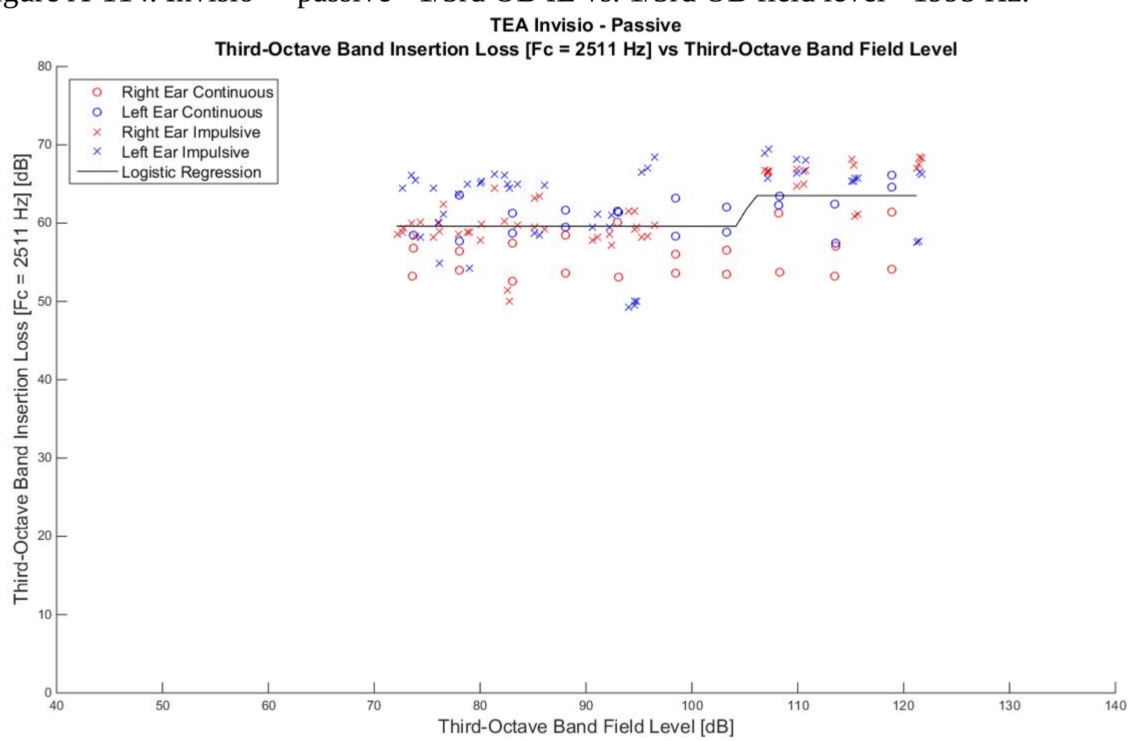

Figure A-115. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

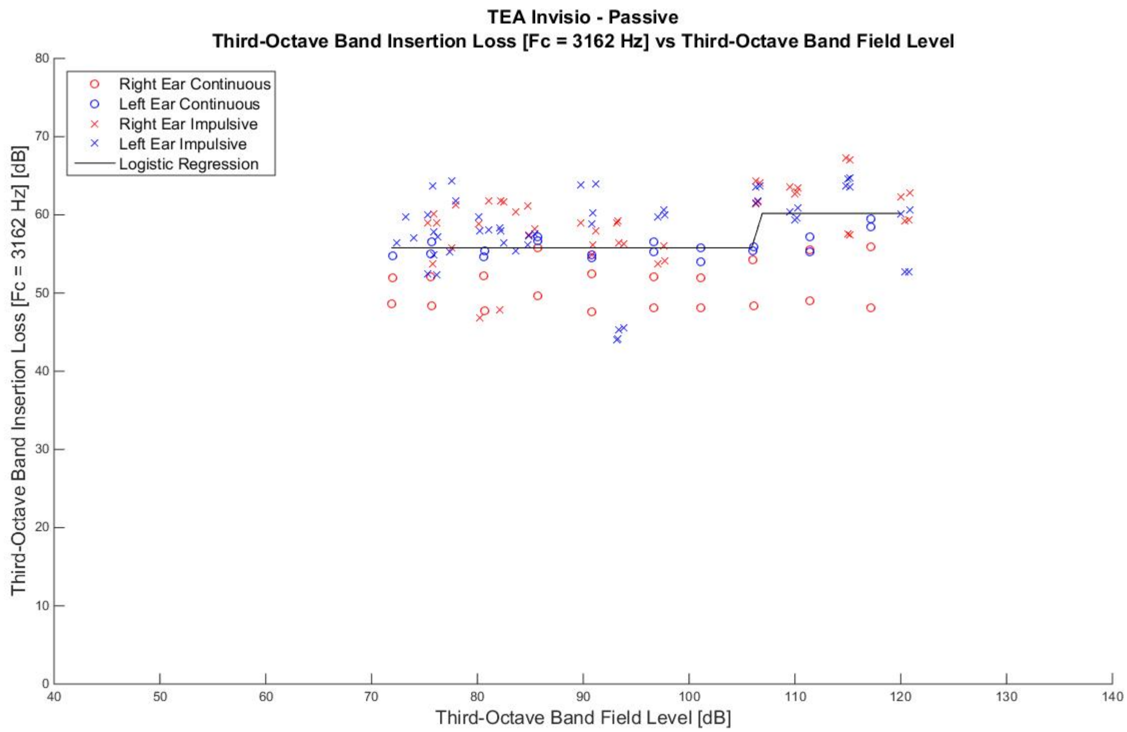

Figure A-116. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

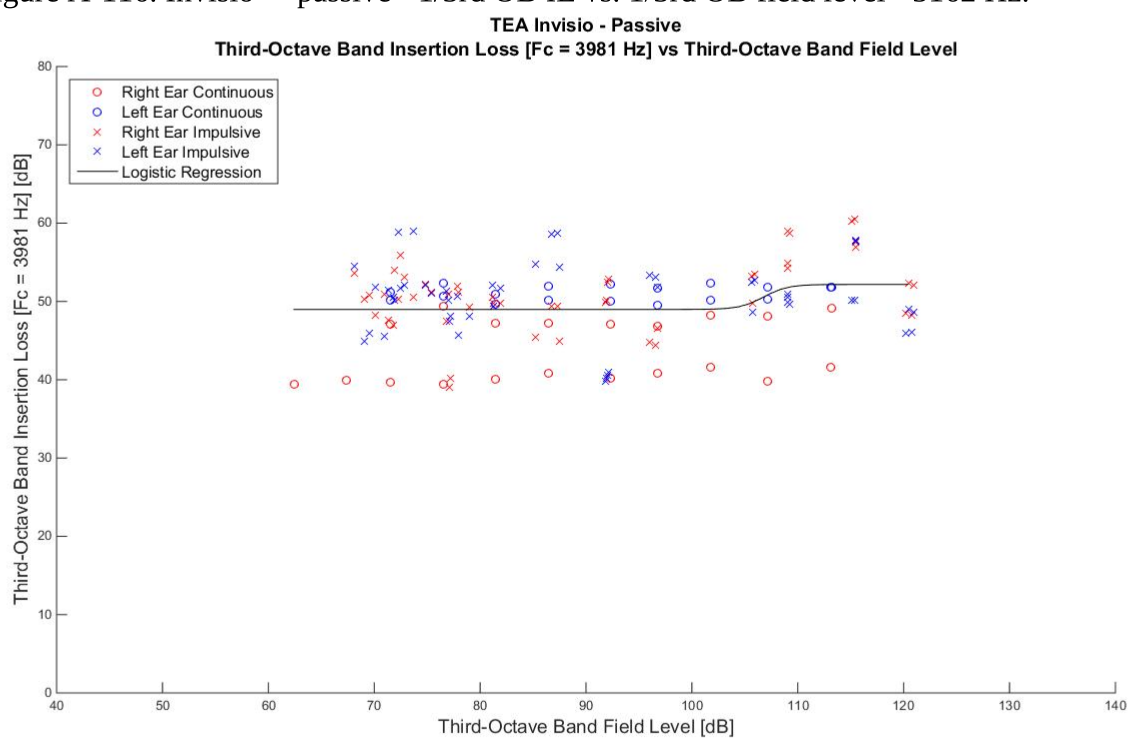

Figure A-117. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

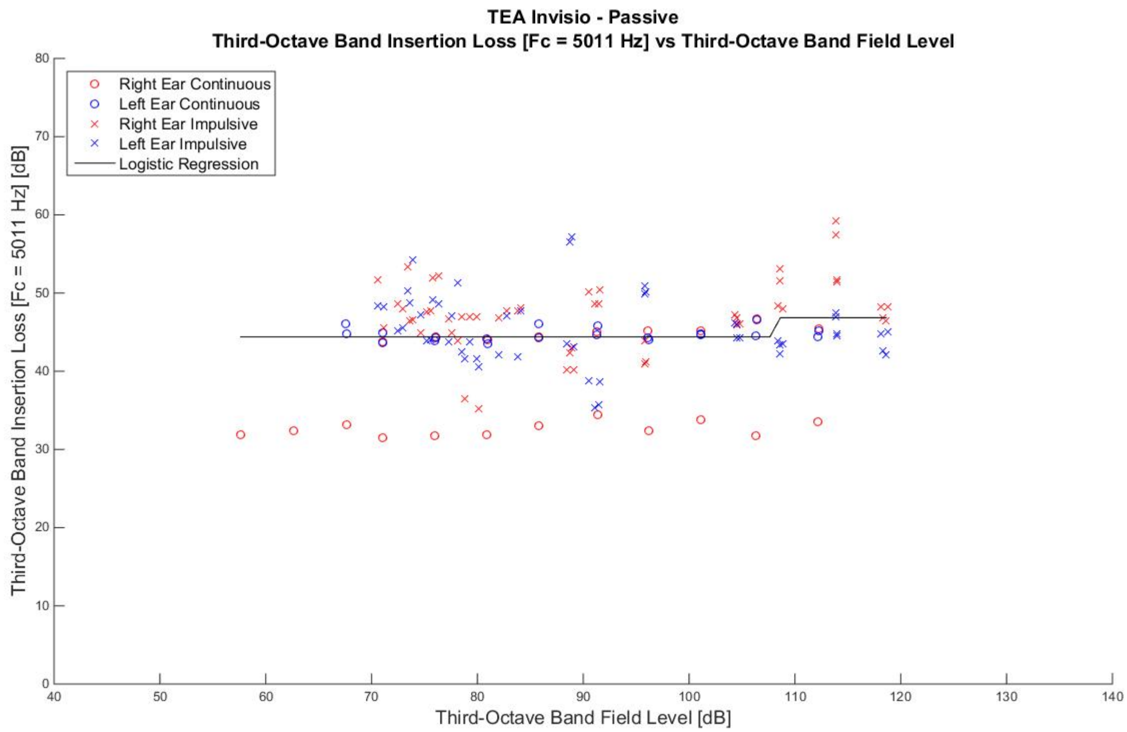

Figure A-118. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

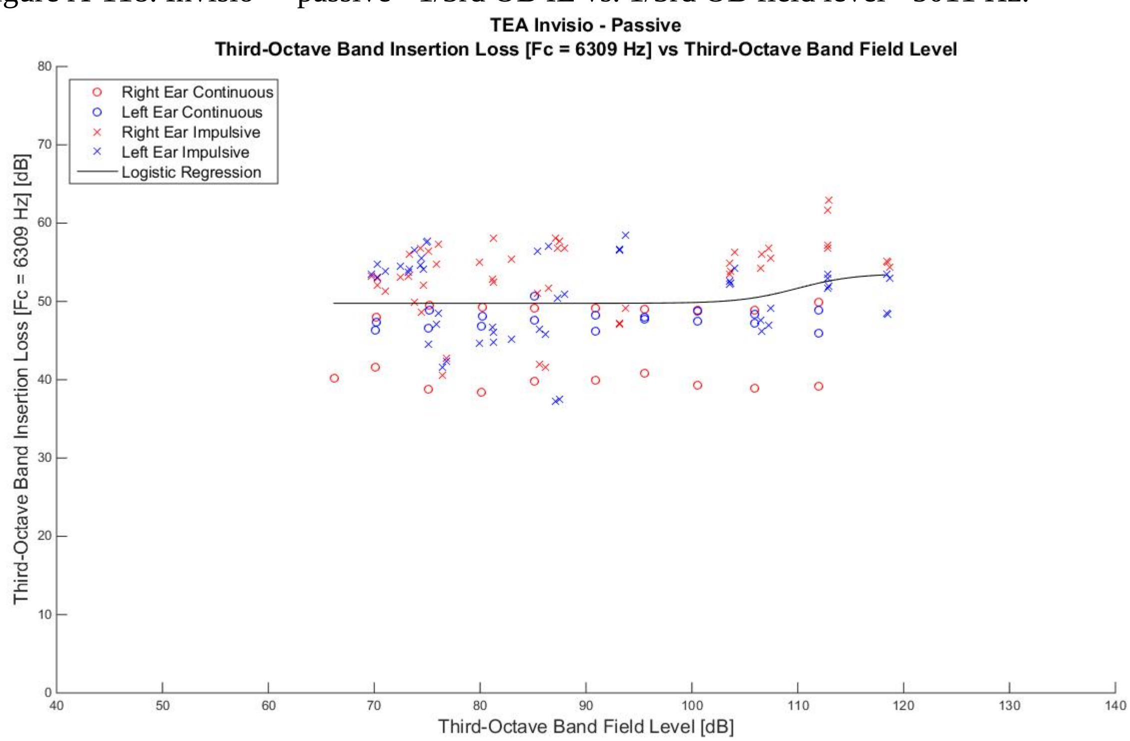

Figure A-119. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

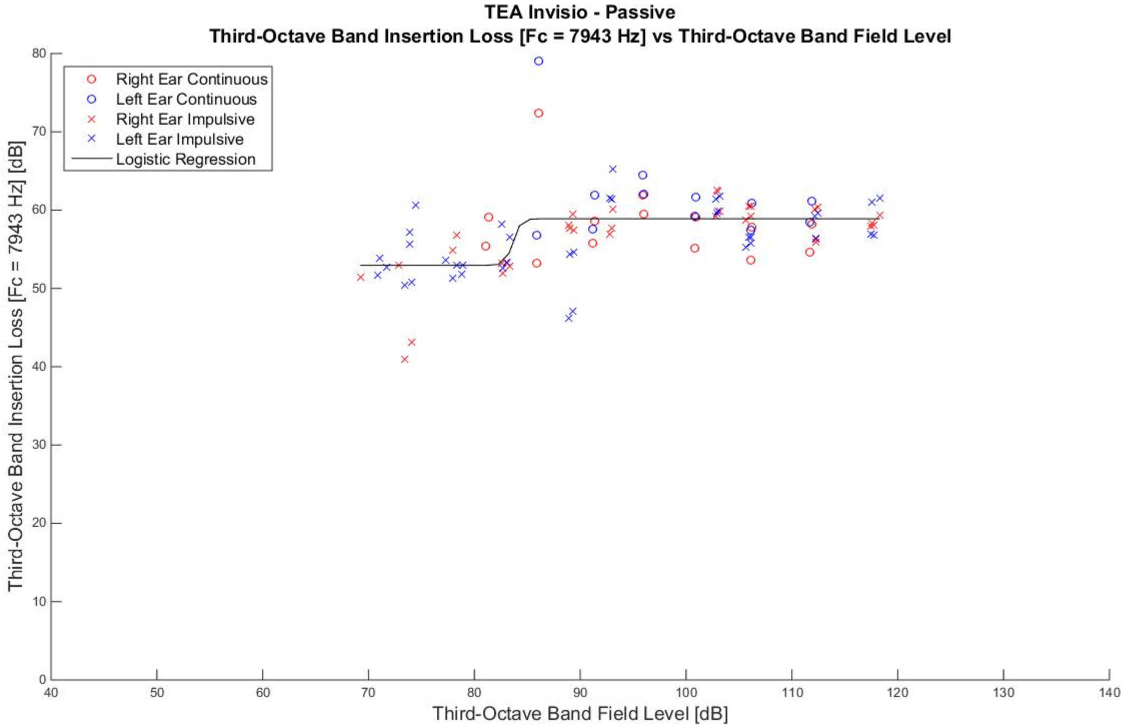

Figure A-120. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

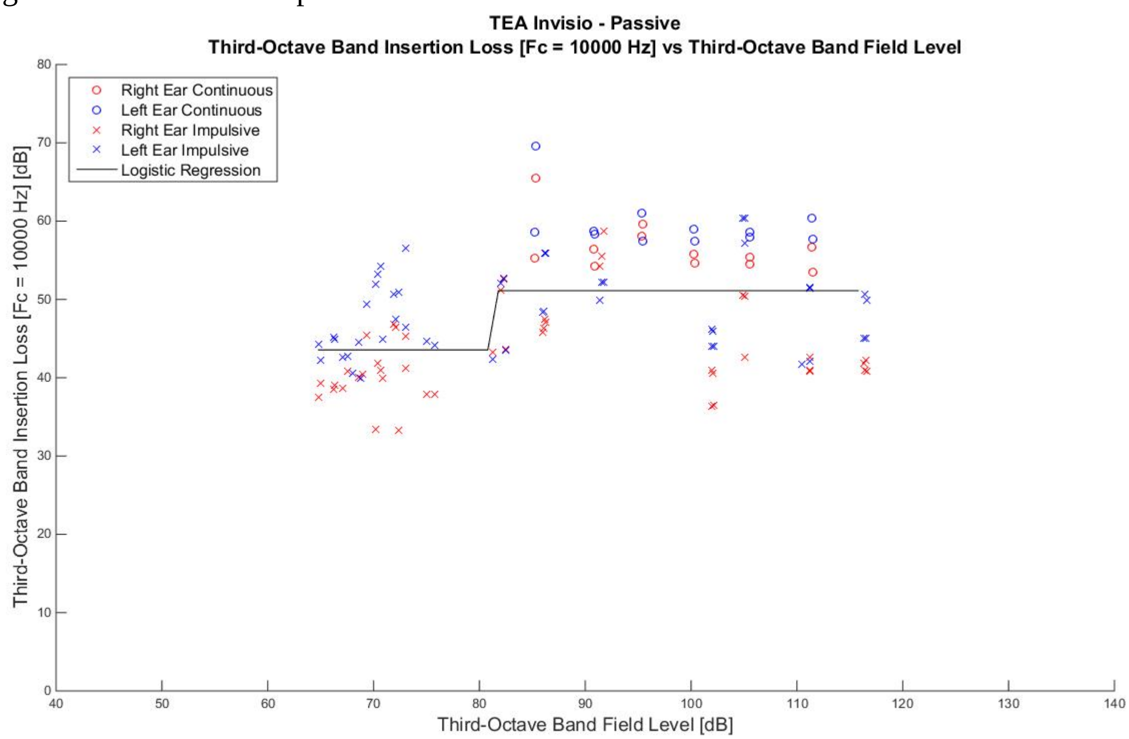

Figure A-121. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

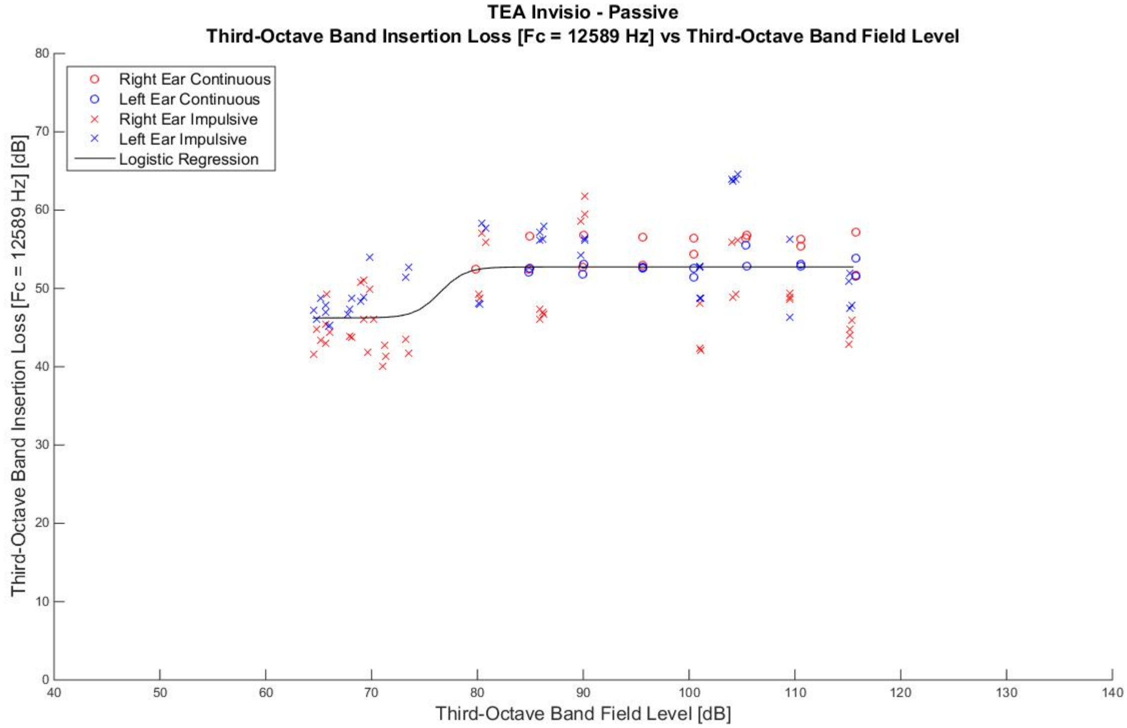

Figure A-122. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

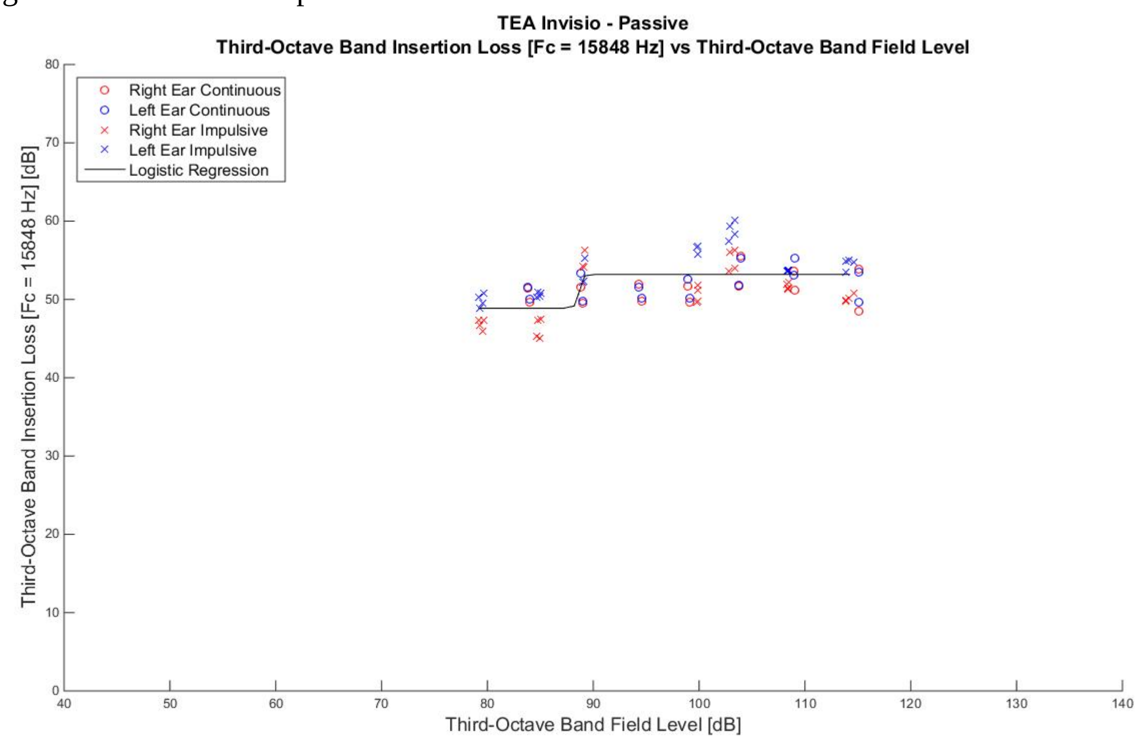

Figure A-123. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

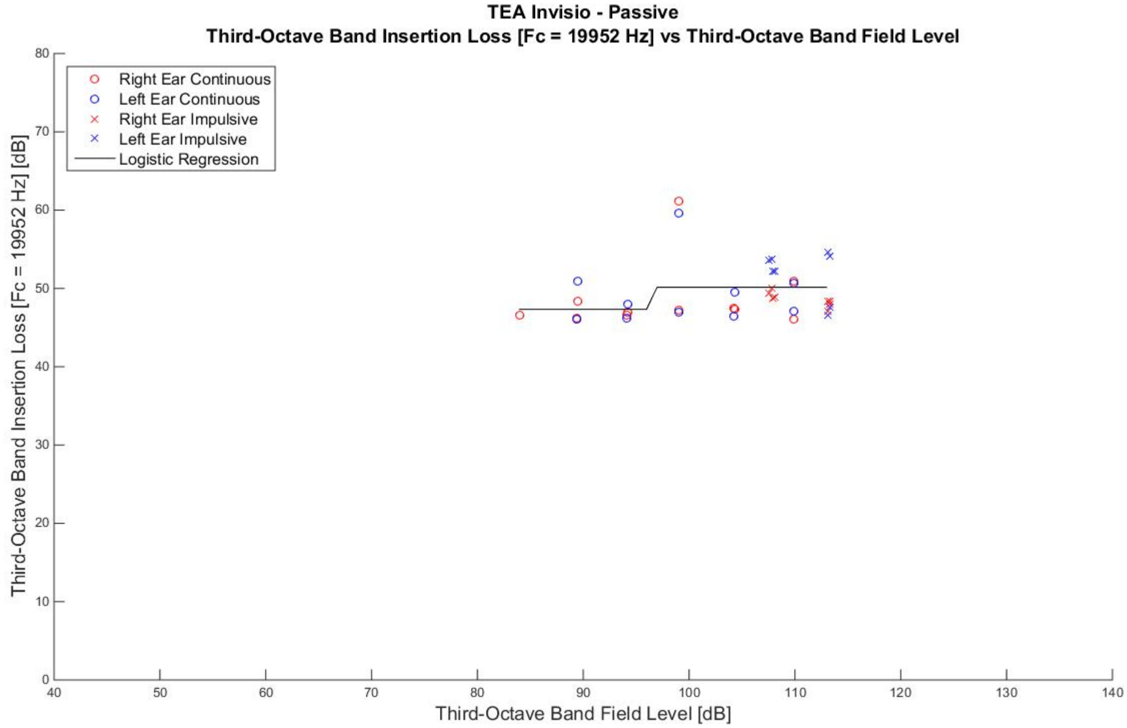

Figure A-124. Invisio® - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

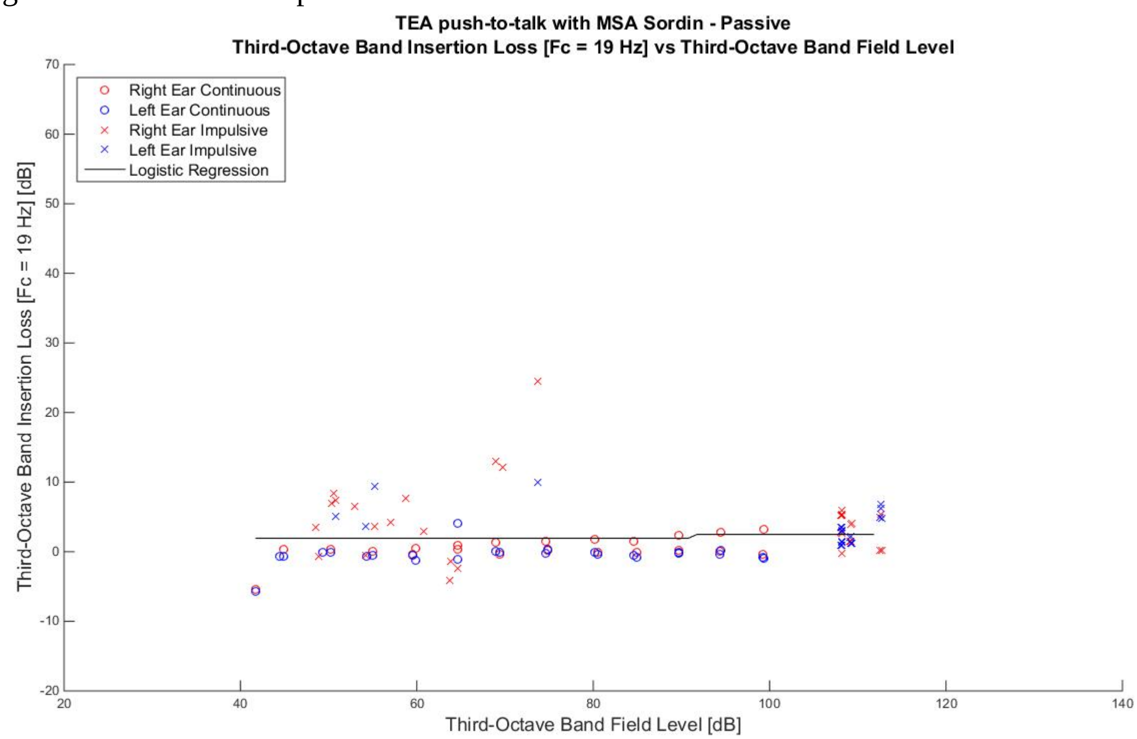

Figure A-125. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

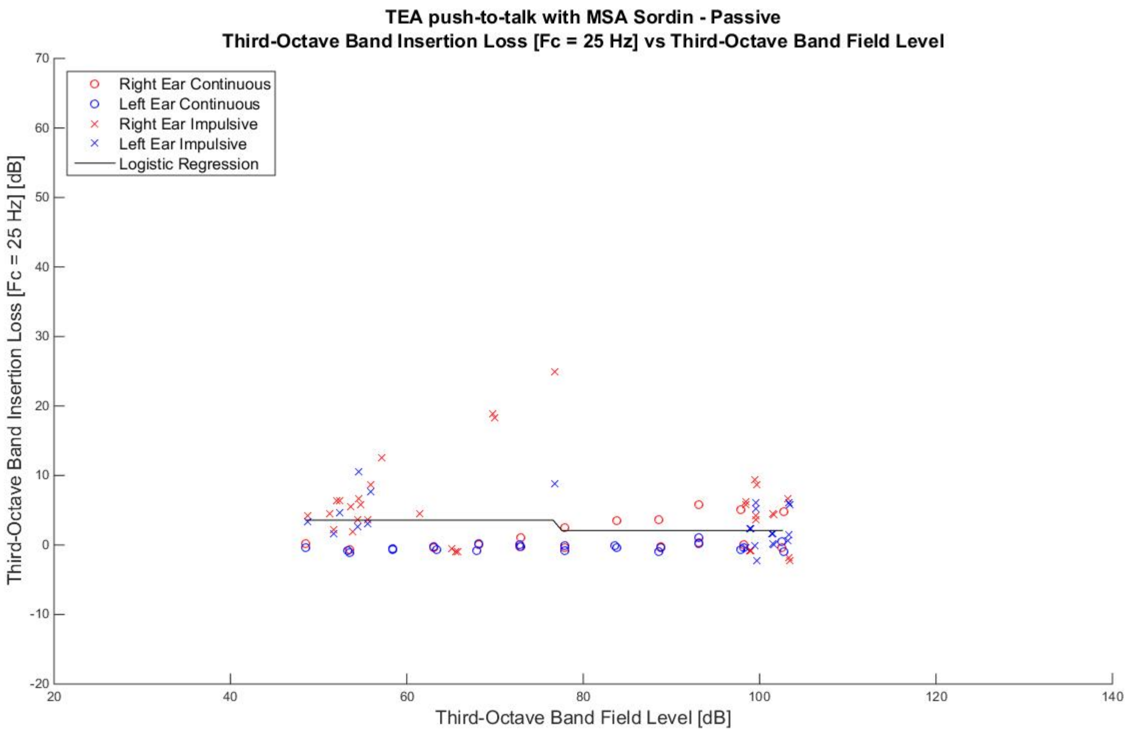

Figure A-126. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

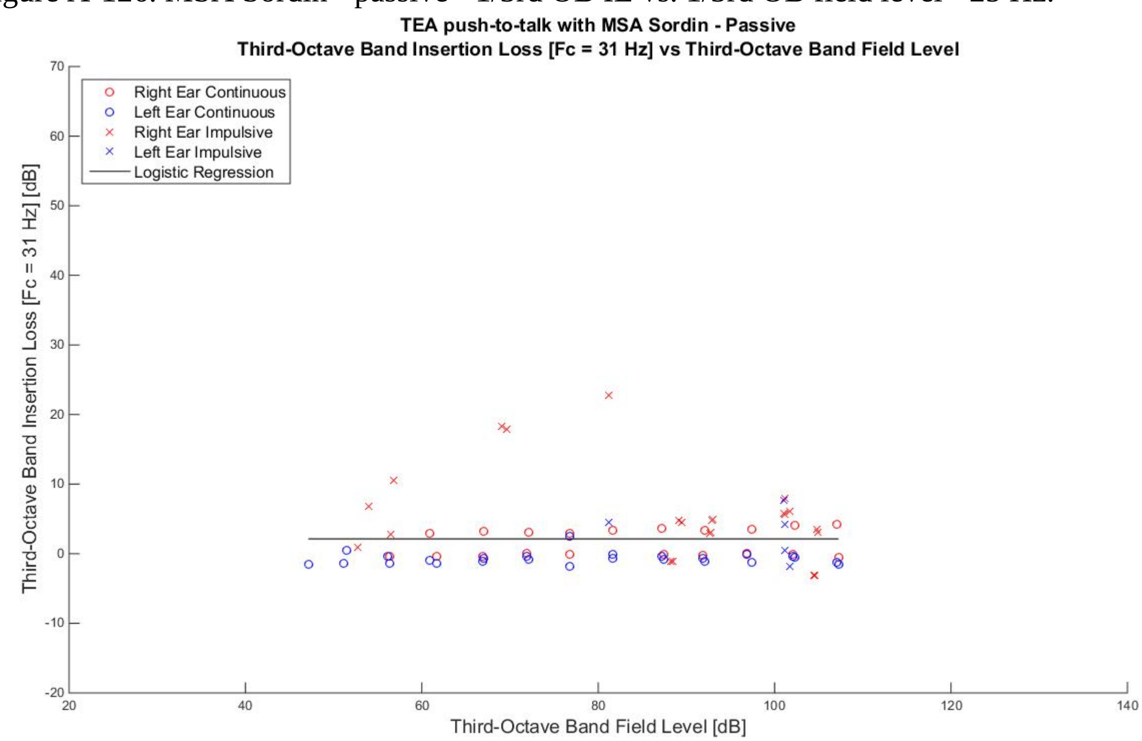

Figure A-127. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

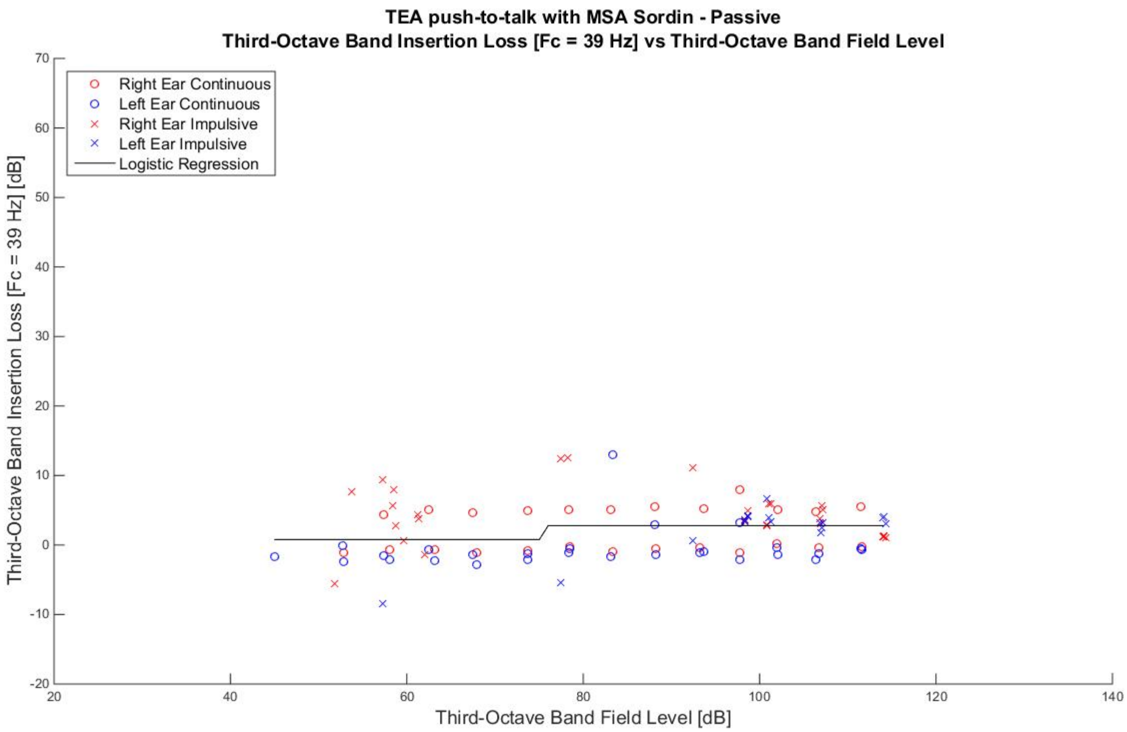

Figure A-128. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

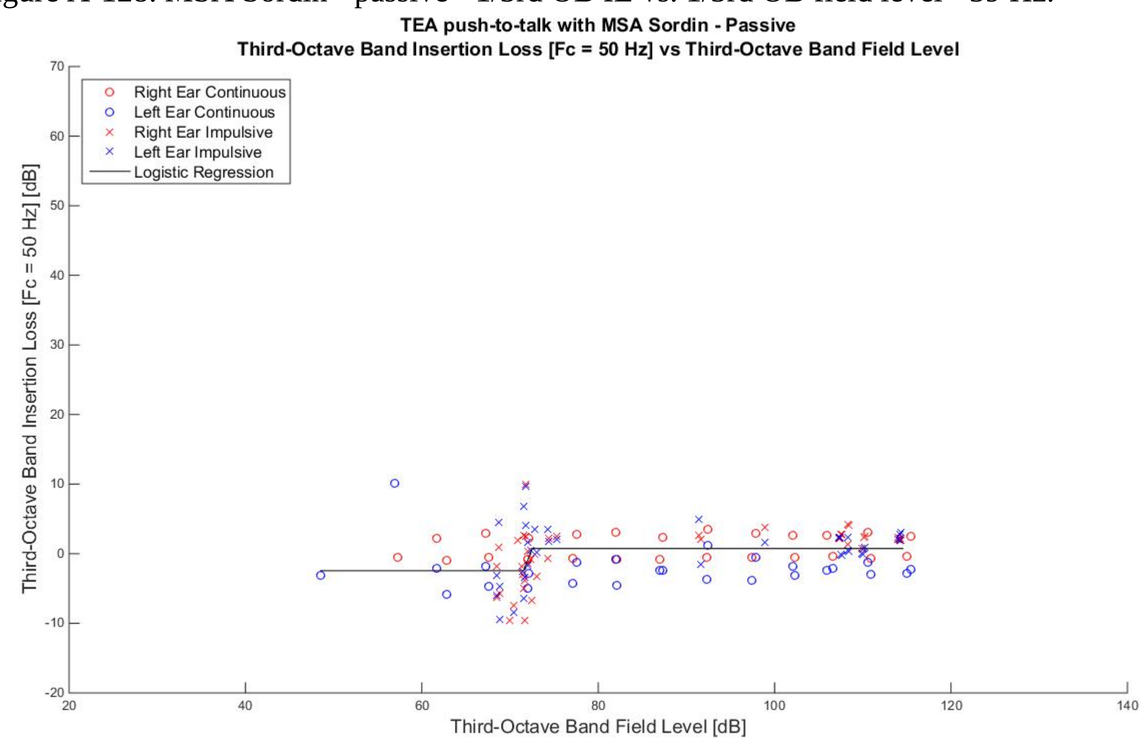

Figure A-129. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

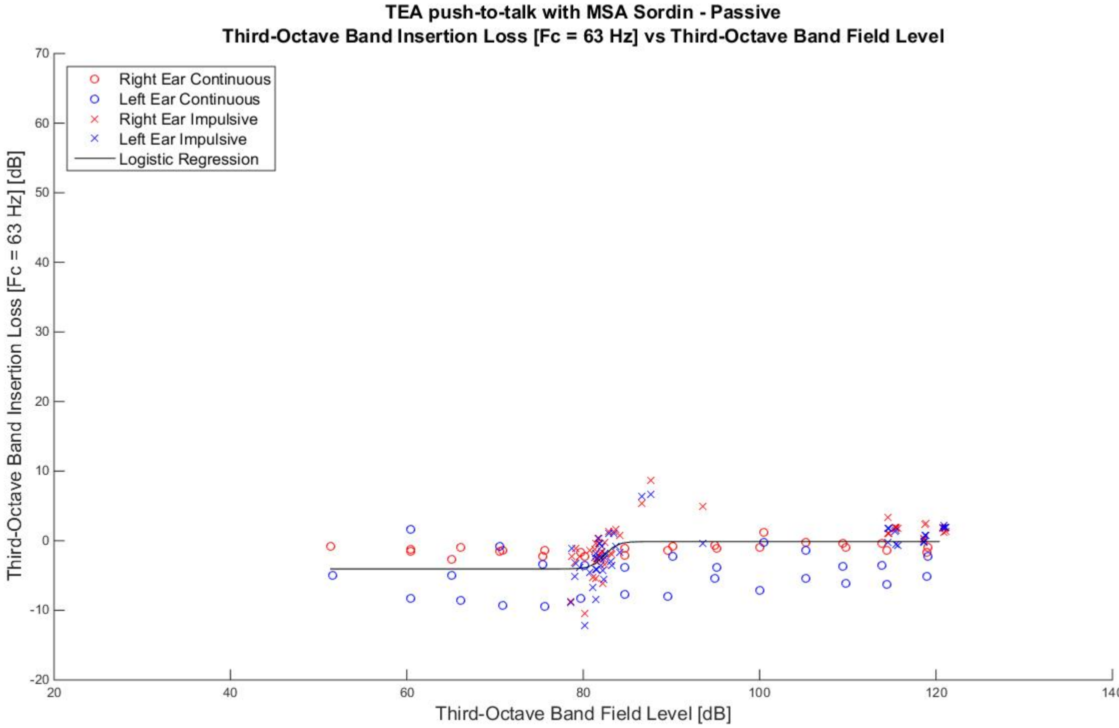

Figure A-130. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

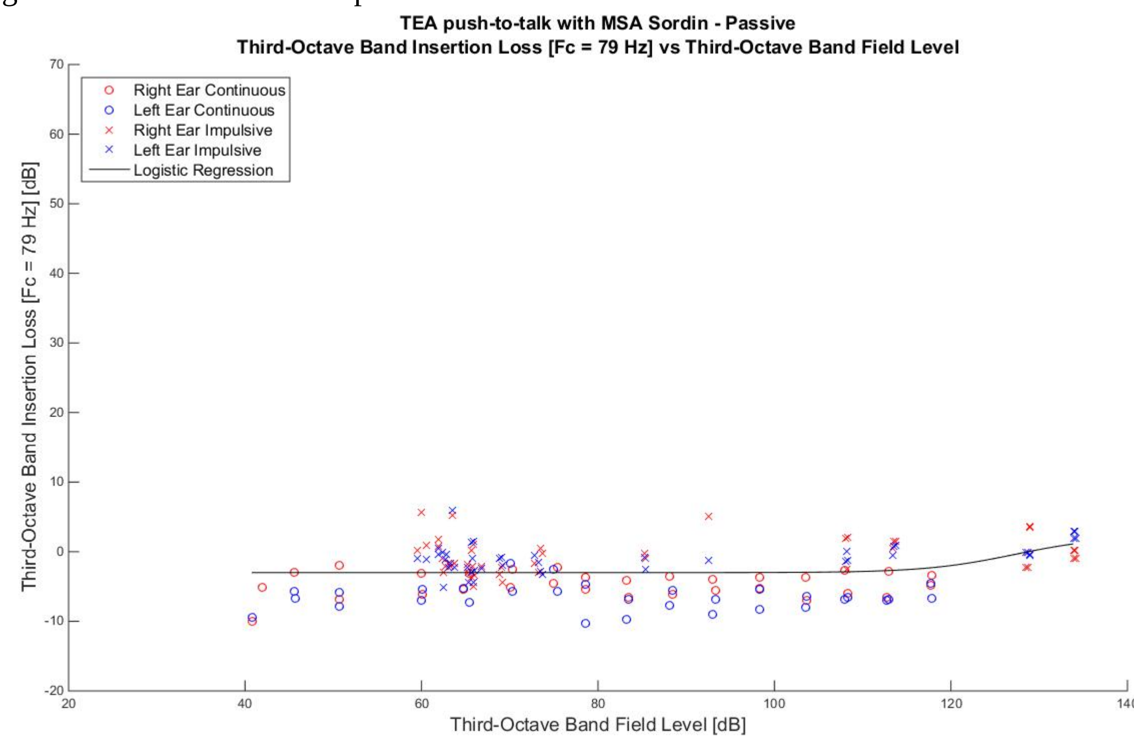

Figure A-131. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

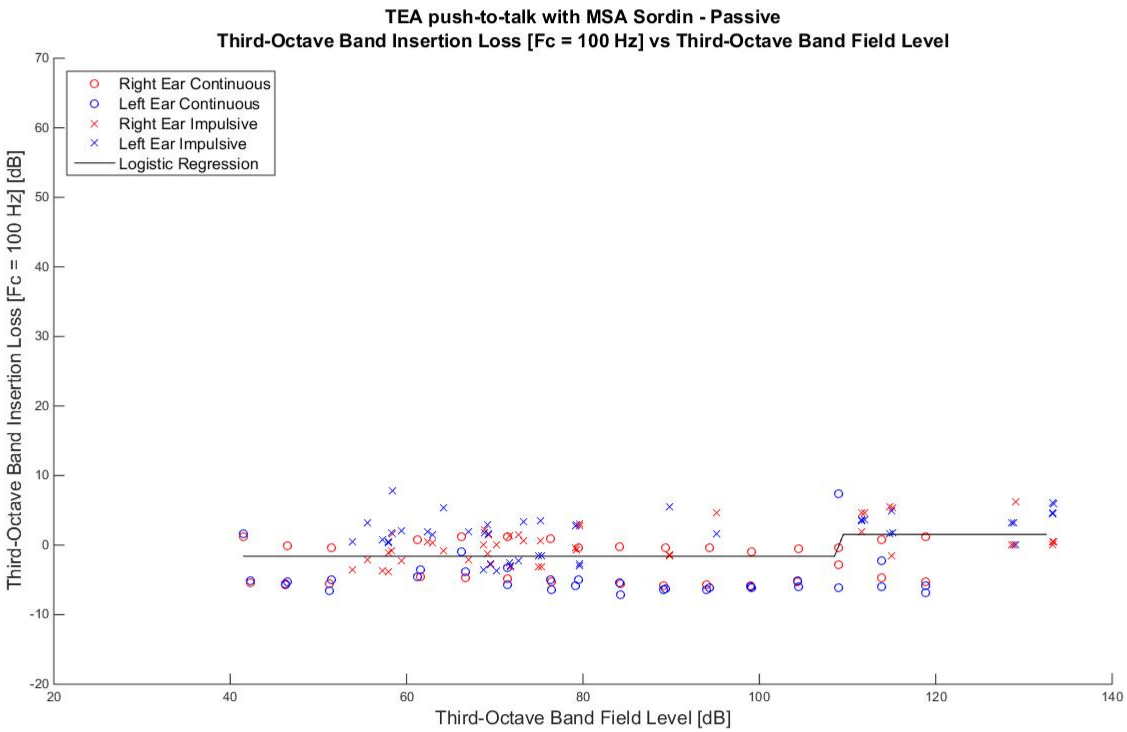

Figure A-132. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

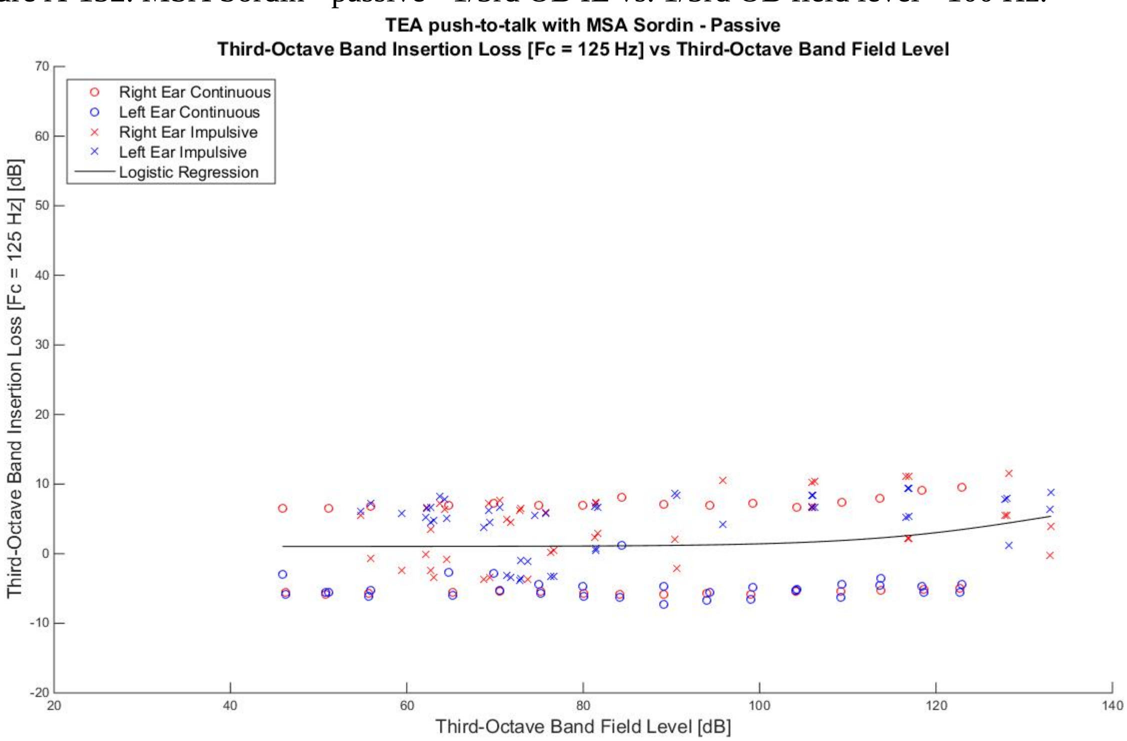

Figure A-133. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

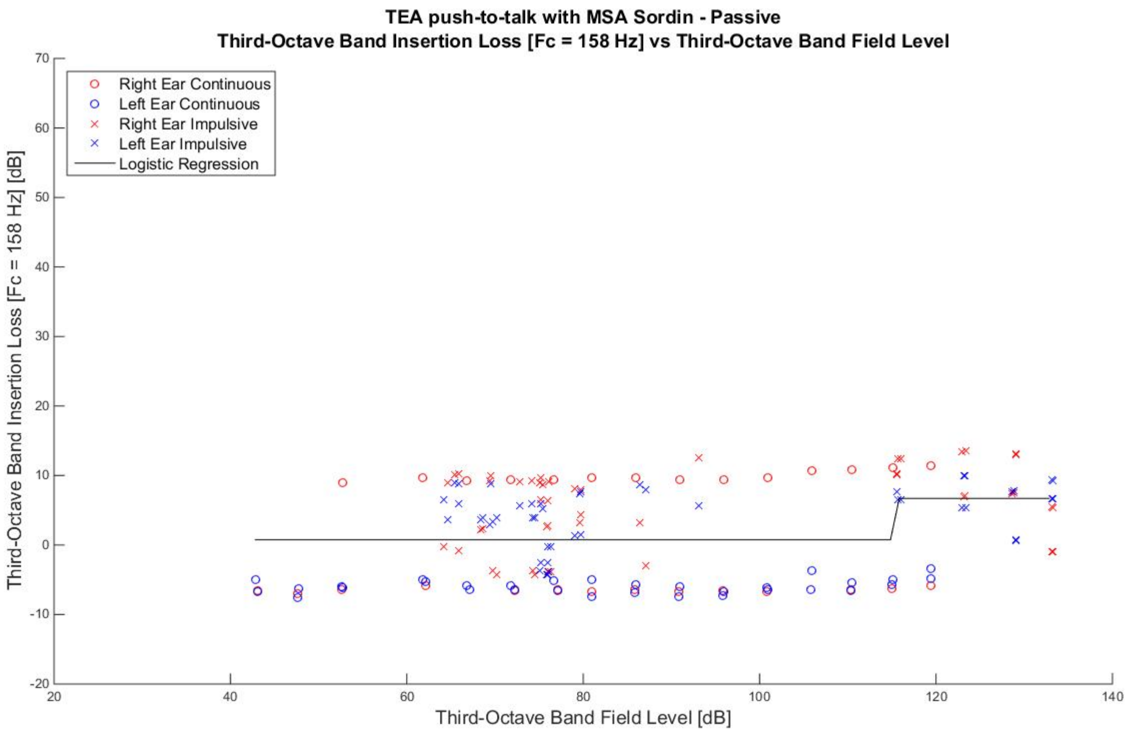

Figure A-134. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

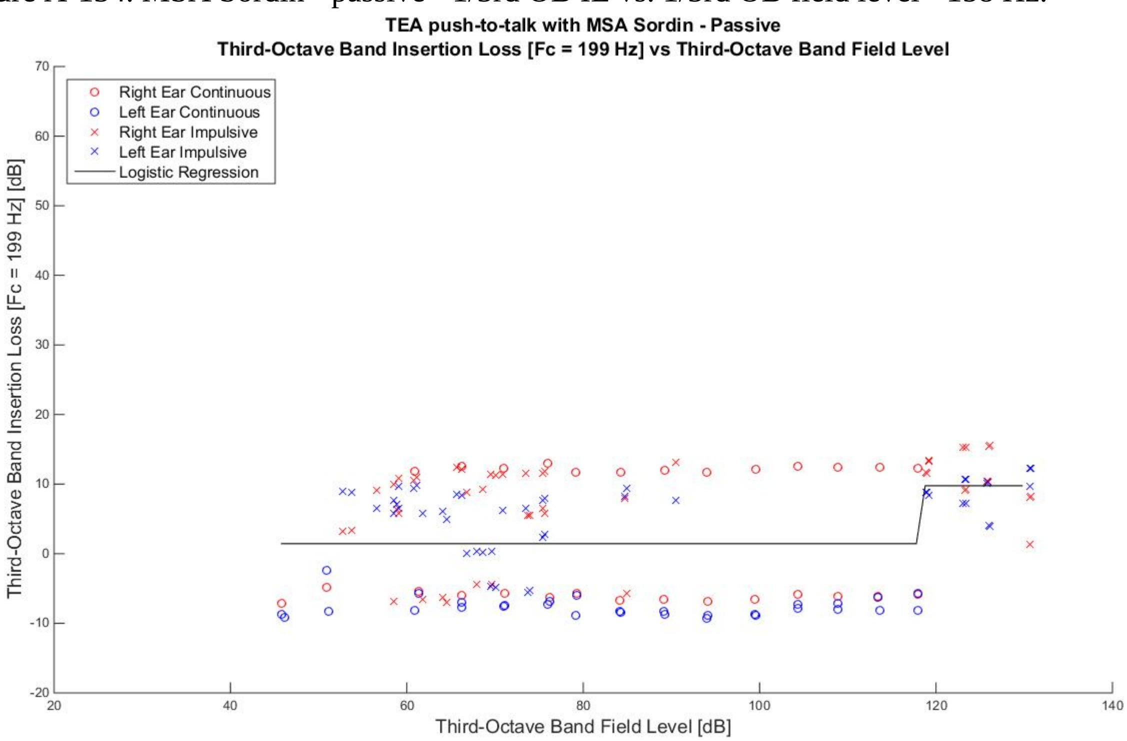

Figure A-135. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

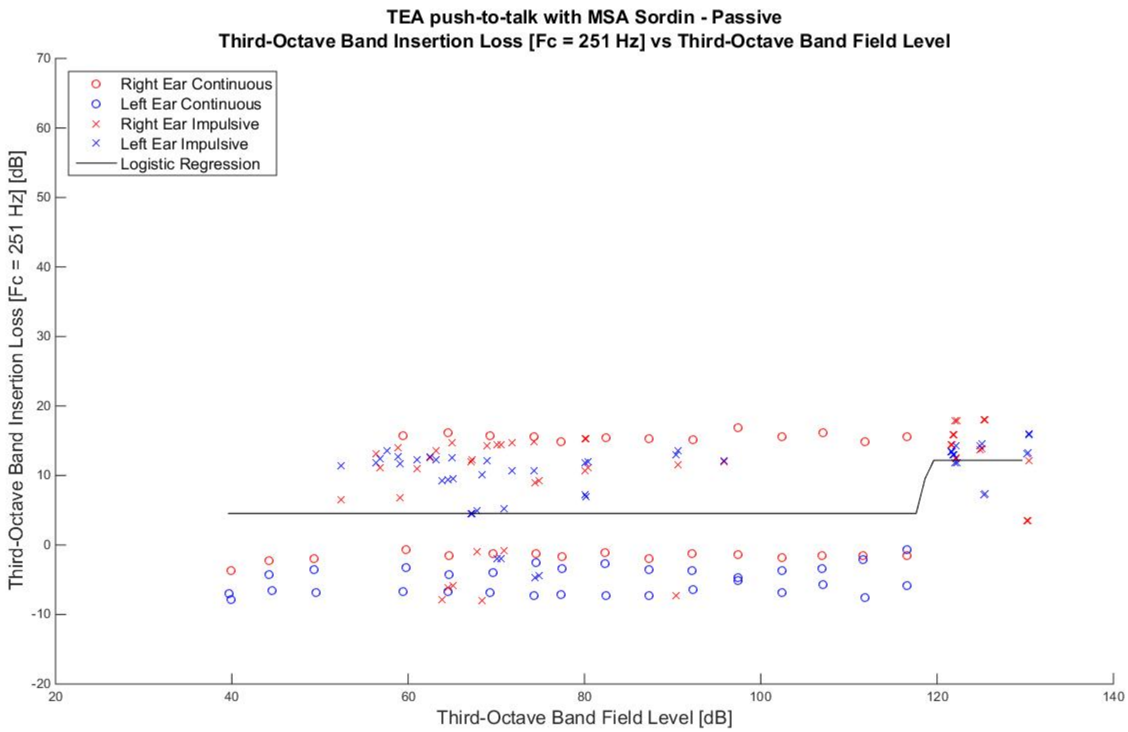

Figure A-136. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

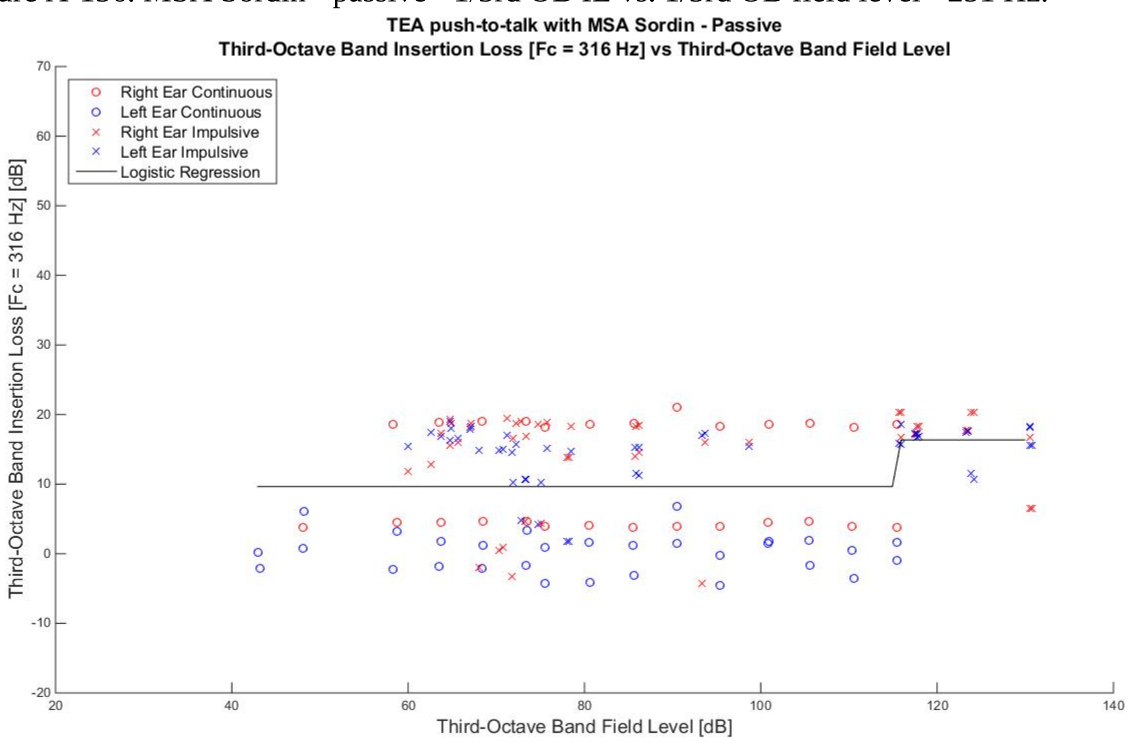

Figure A-137. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

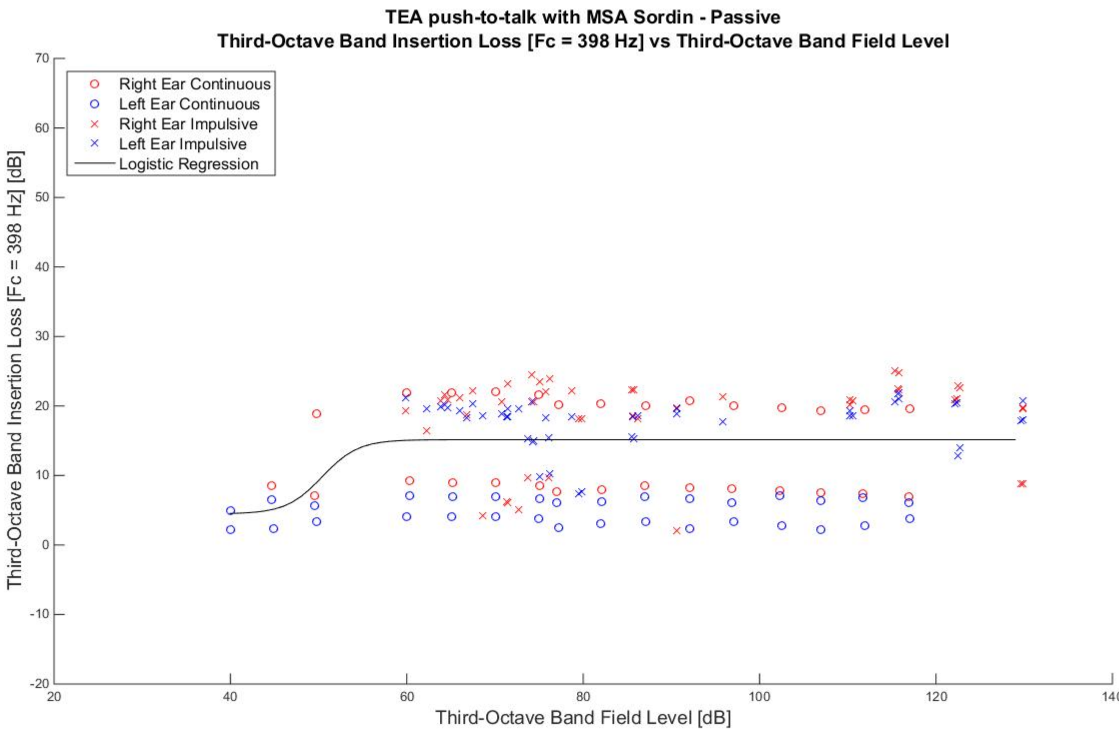

Figure A-138. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

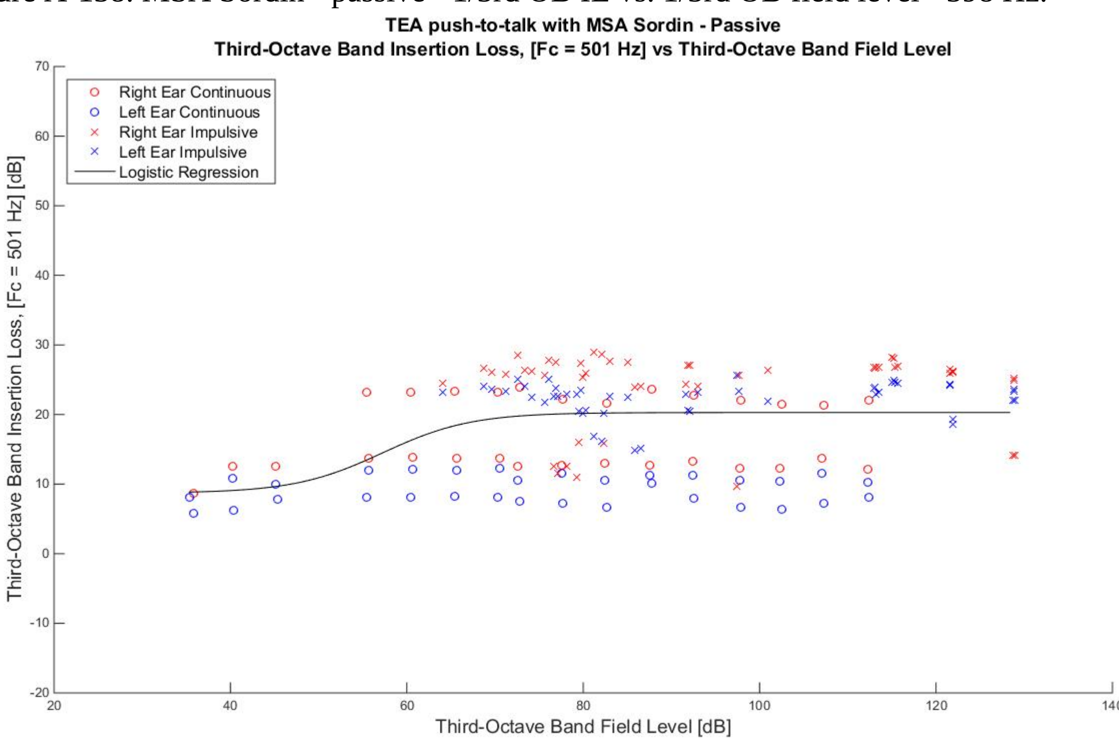

Figure A-139. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

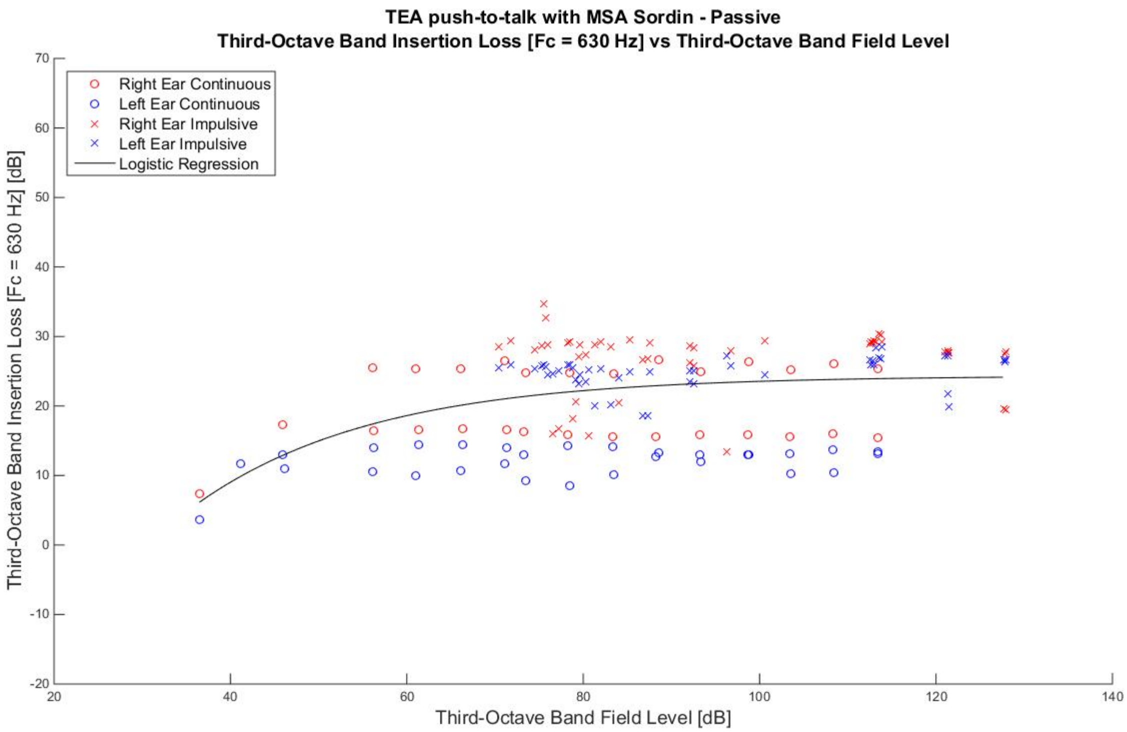

Figure A-140. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

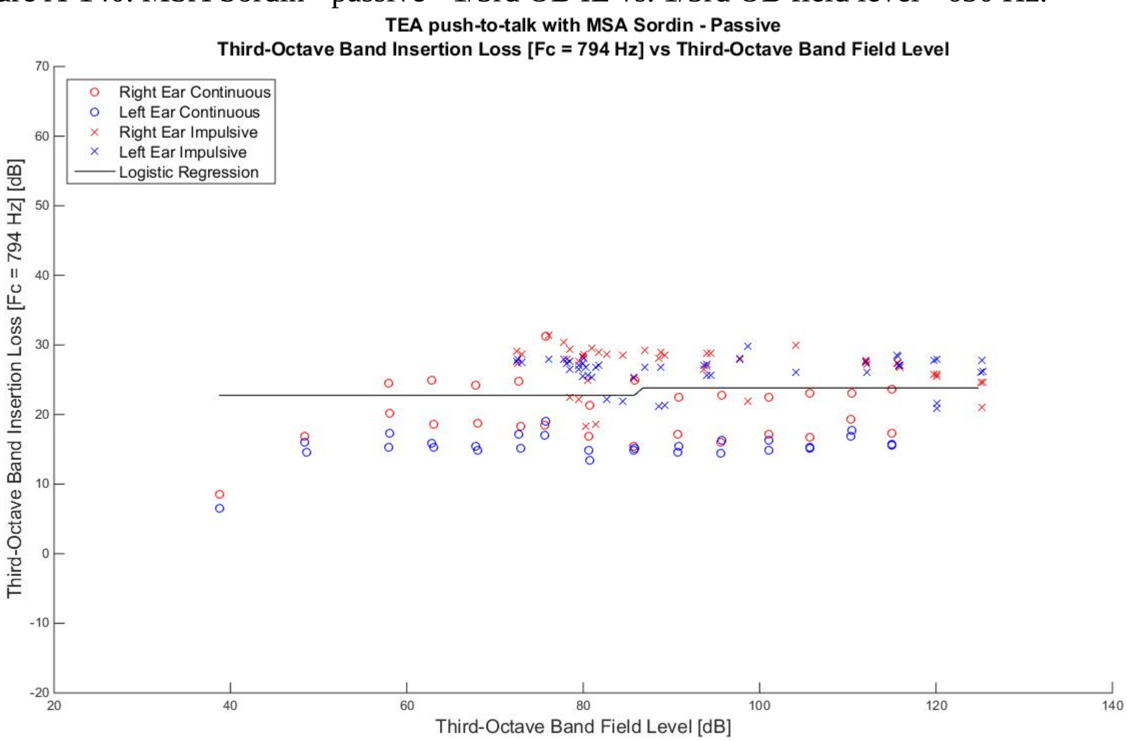

Figure A-141. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

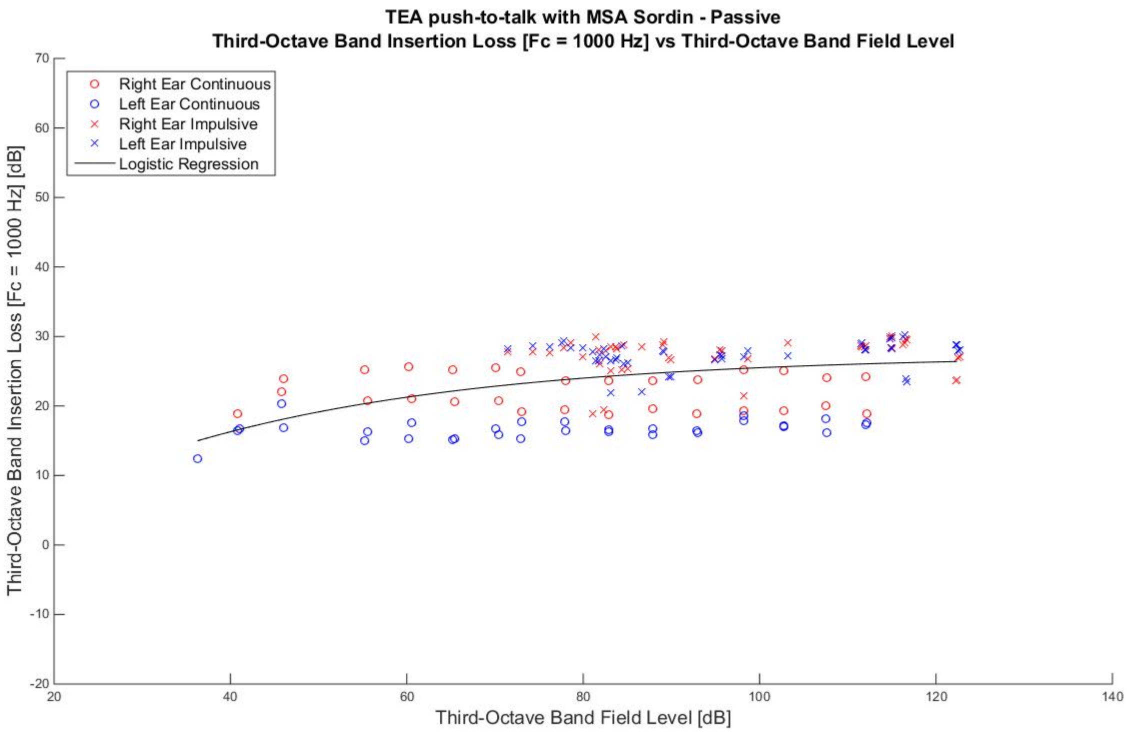

Figure A-142. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

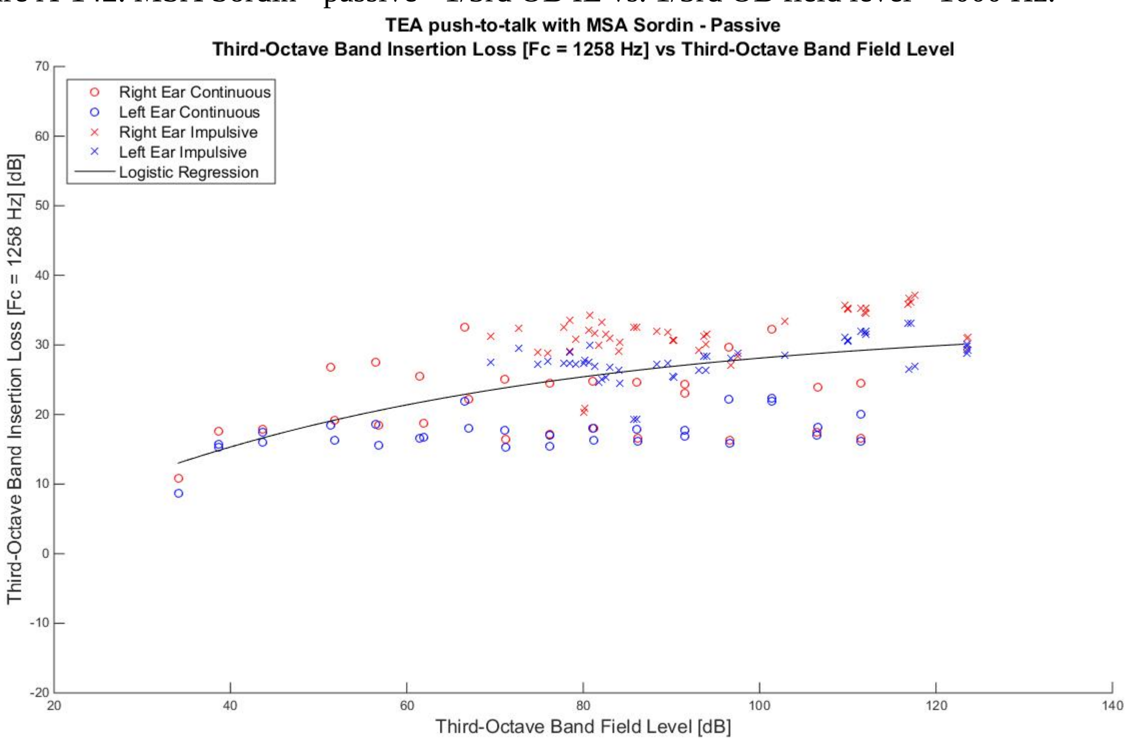

Figure A-143. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

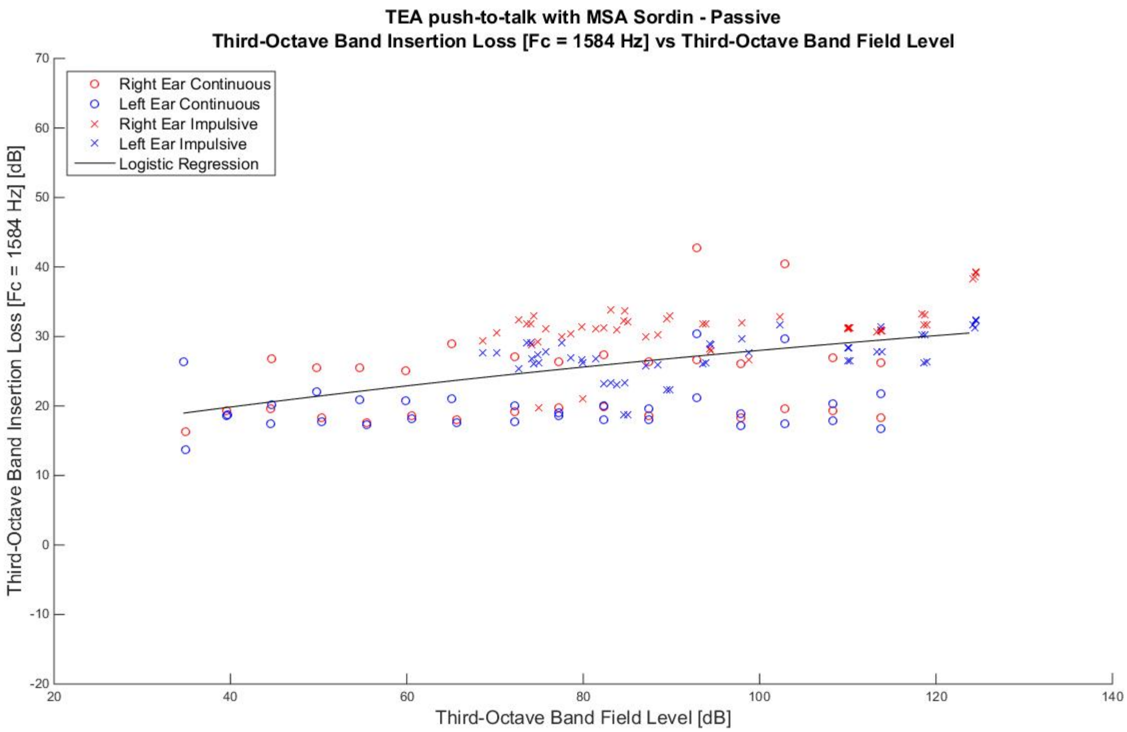

Figure A-144. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

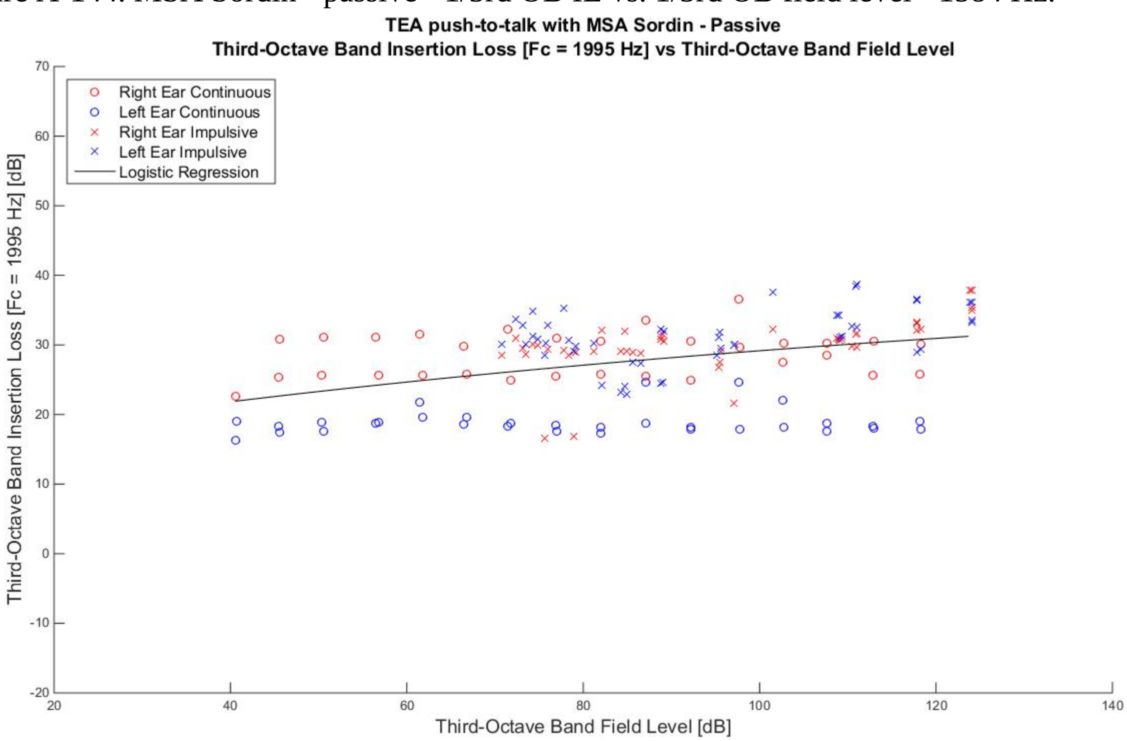

Figure A-145. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

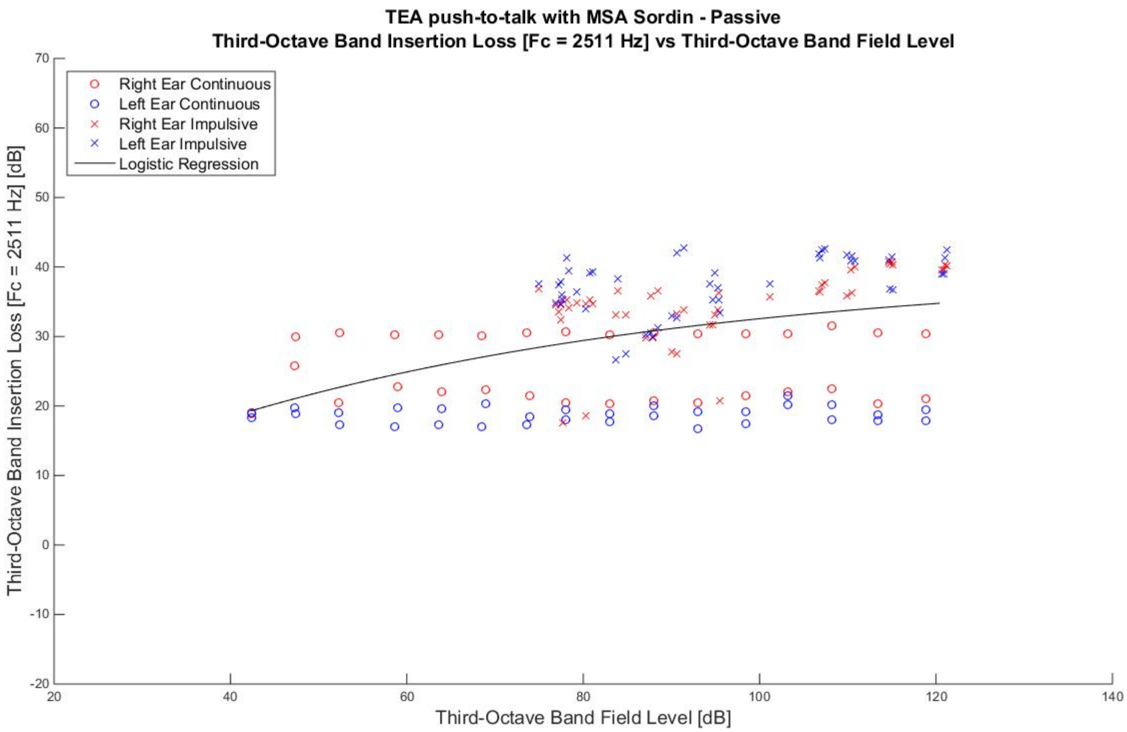

Figure A-146. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

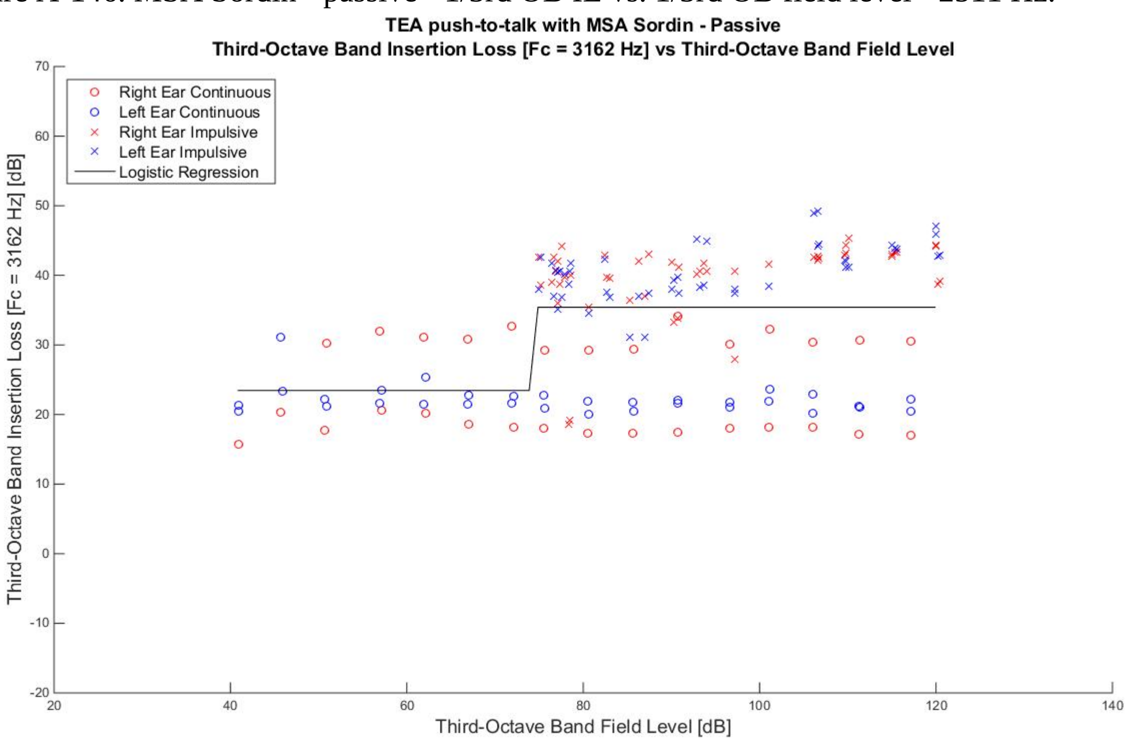

Figure A-147. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

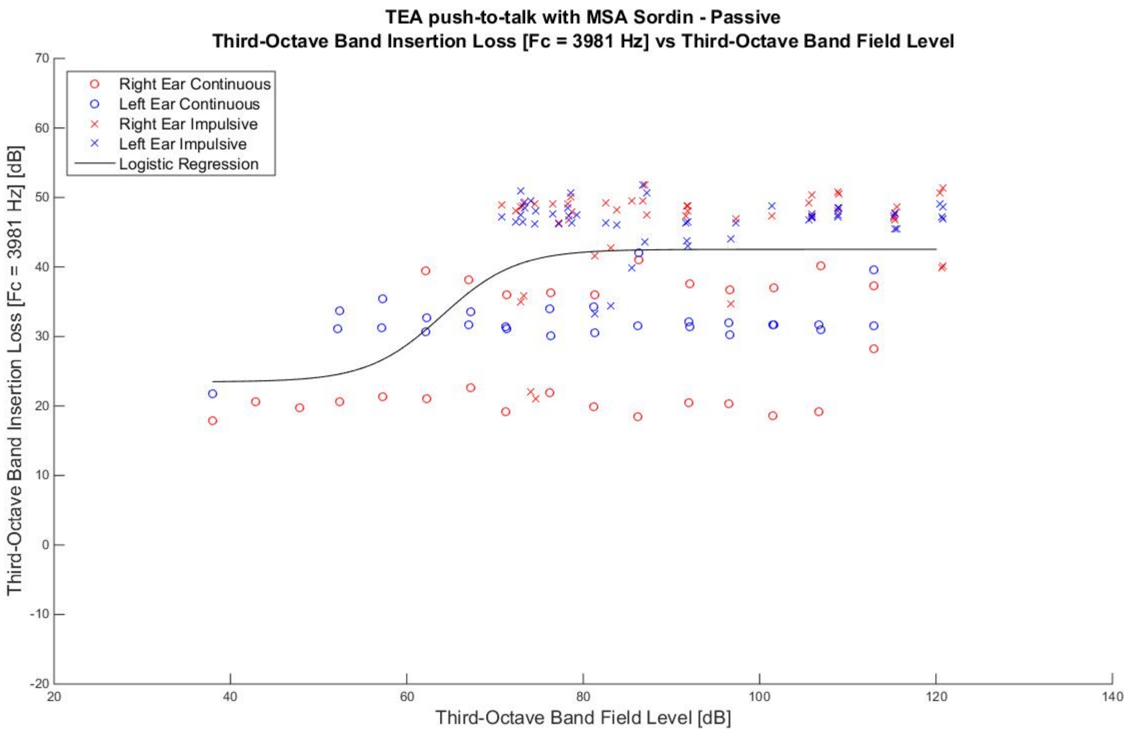

Figure A-148. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

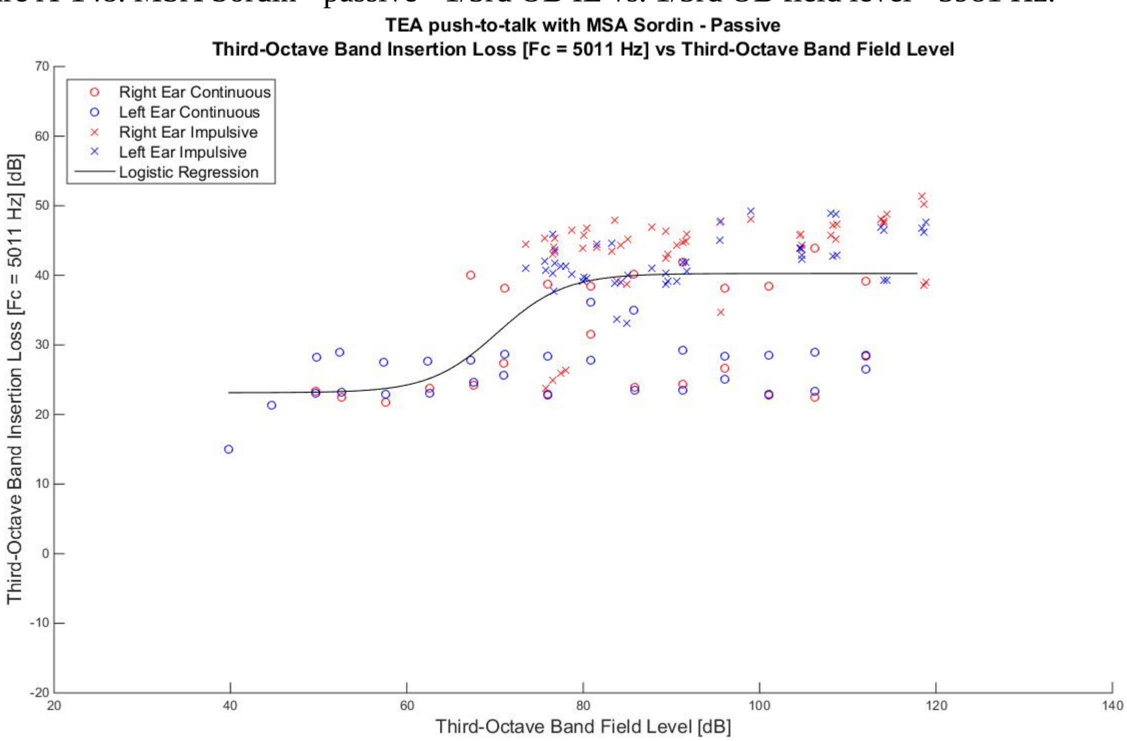

Figure A-149. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

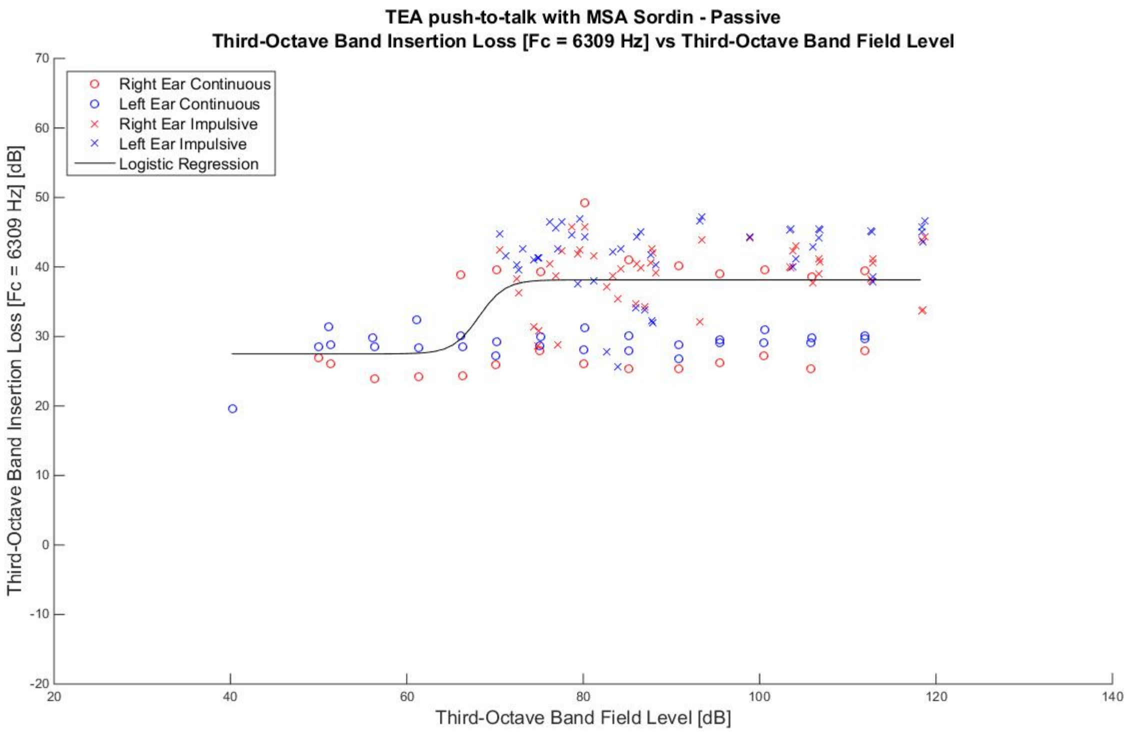

Figure A-150. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

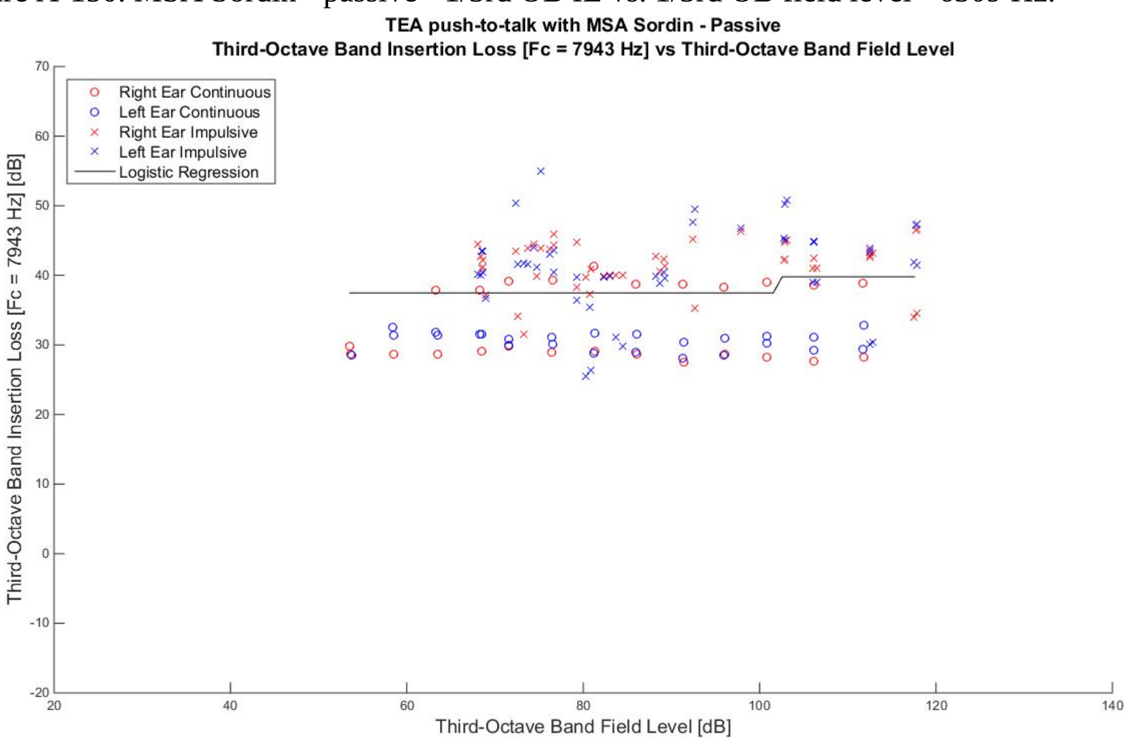

Figure A-151. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

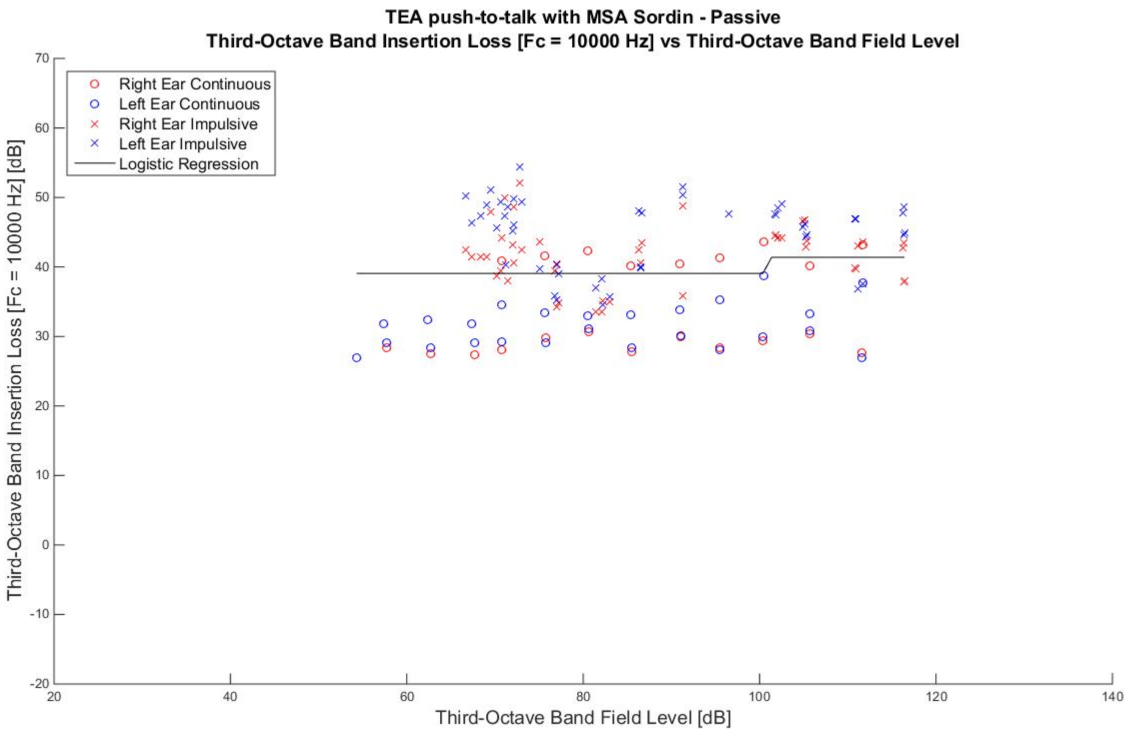

Figure A-152. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

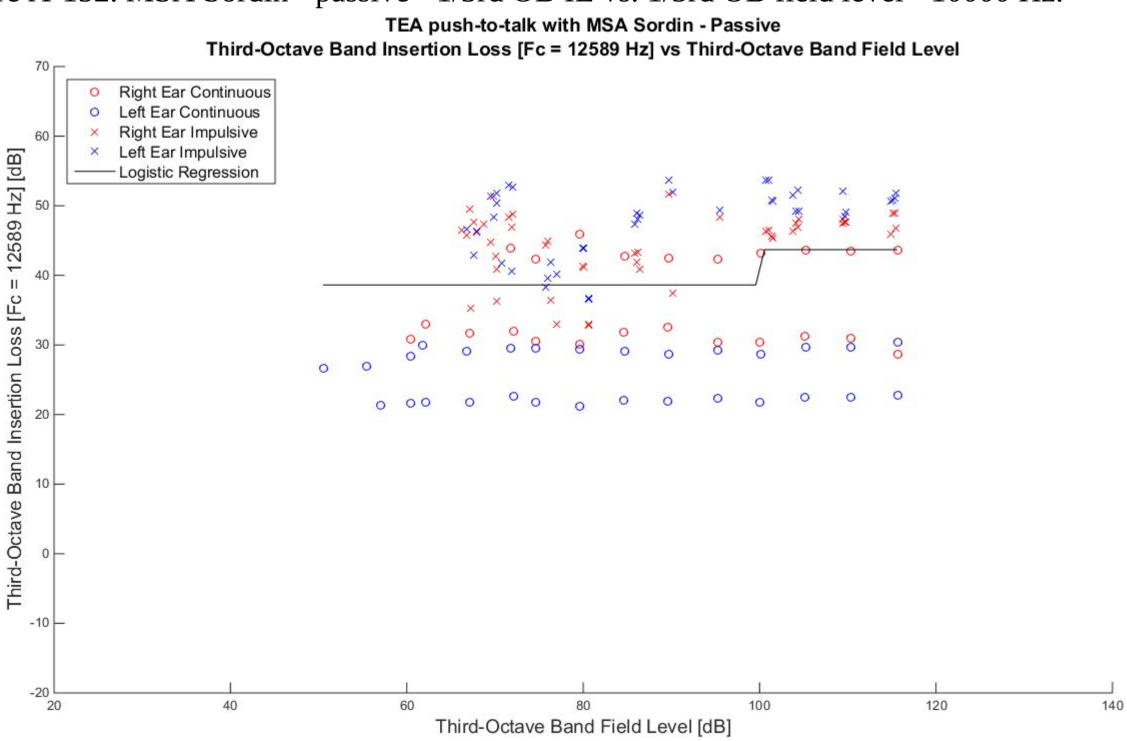

Figure A-153. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

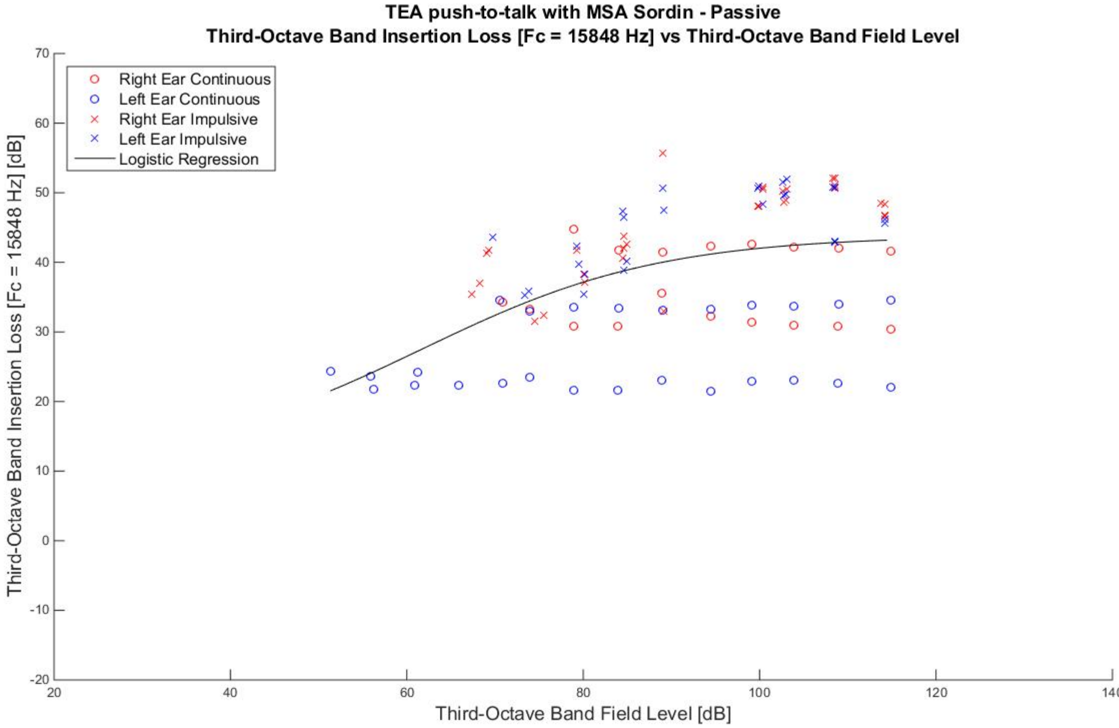

Figure A-154. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

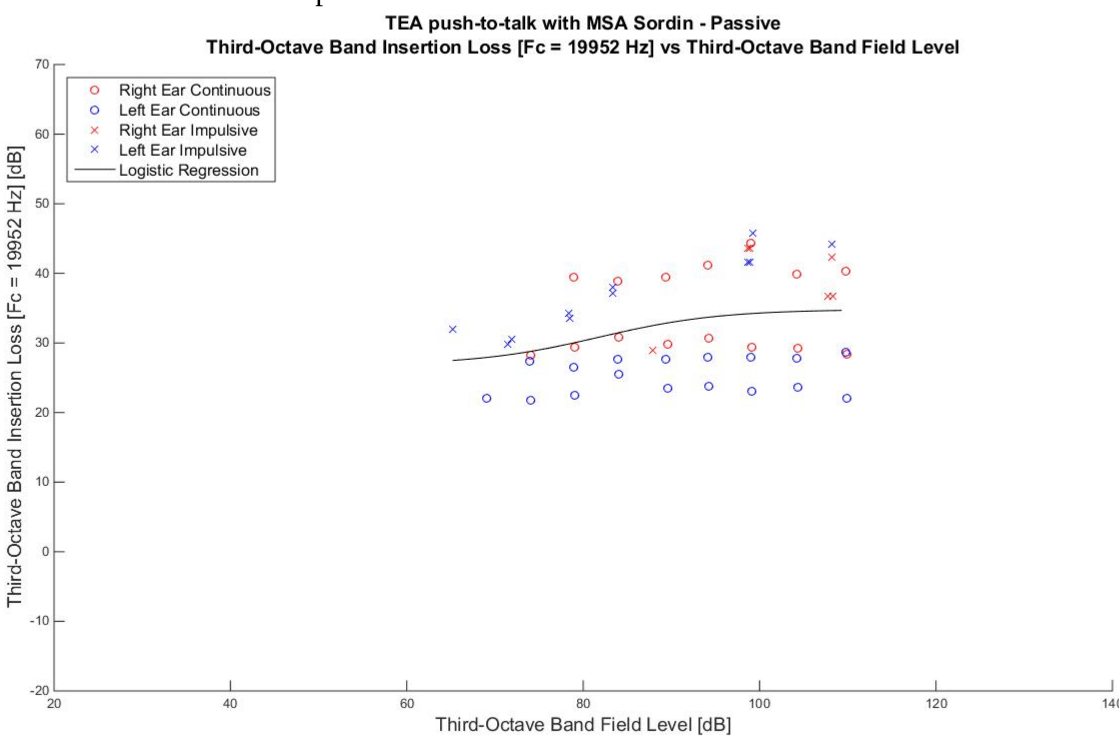

Figure A-155. MSA Sordin - passive - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

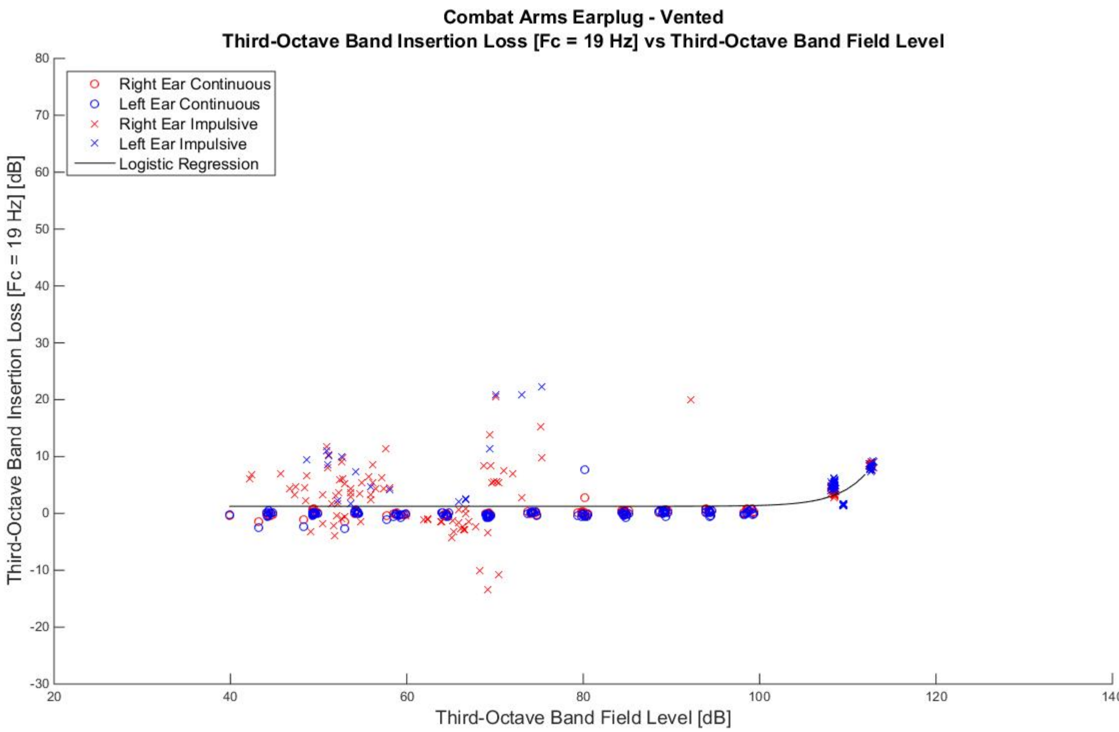

Figure A-156. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

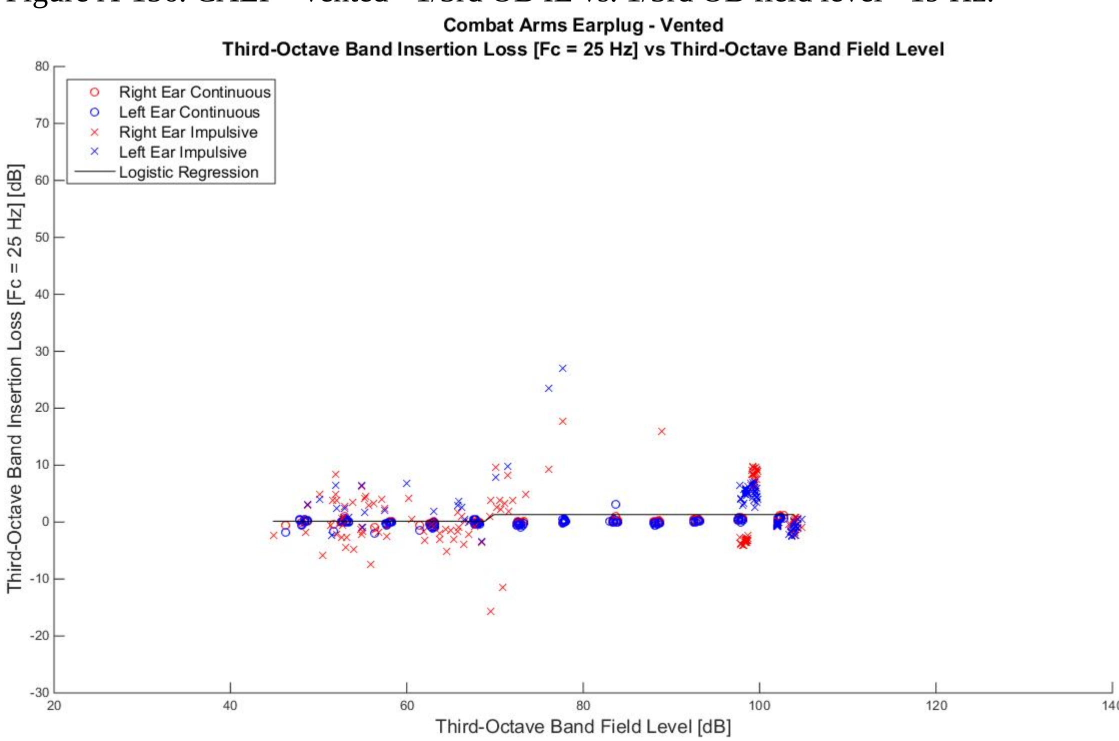

Figure A-157. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

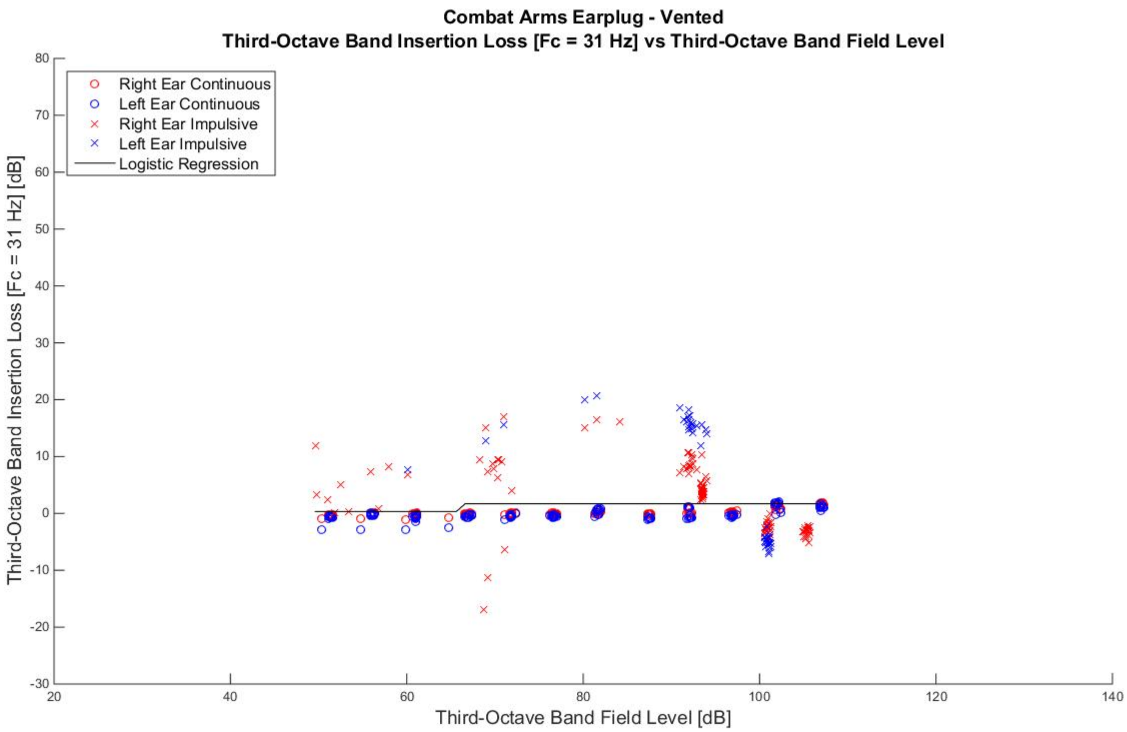

Figure A-158. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

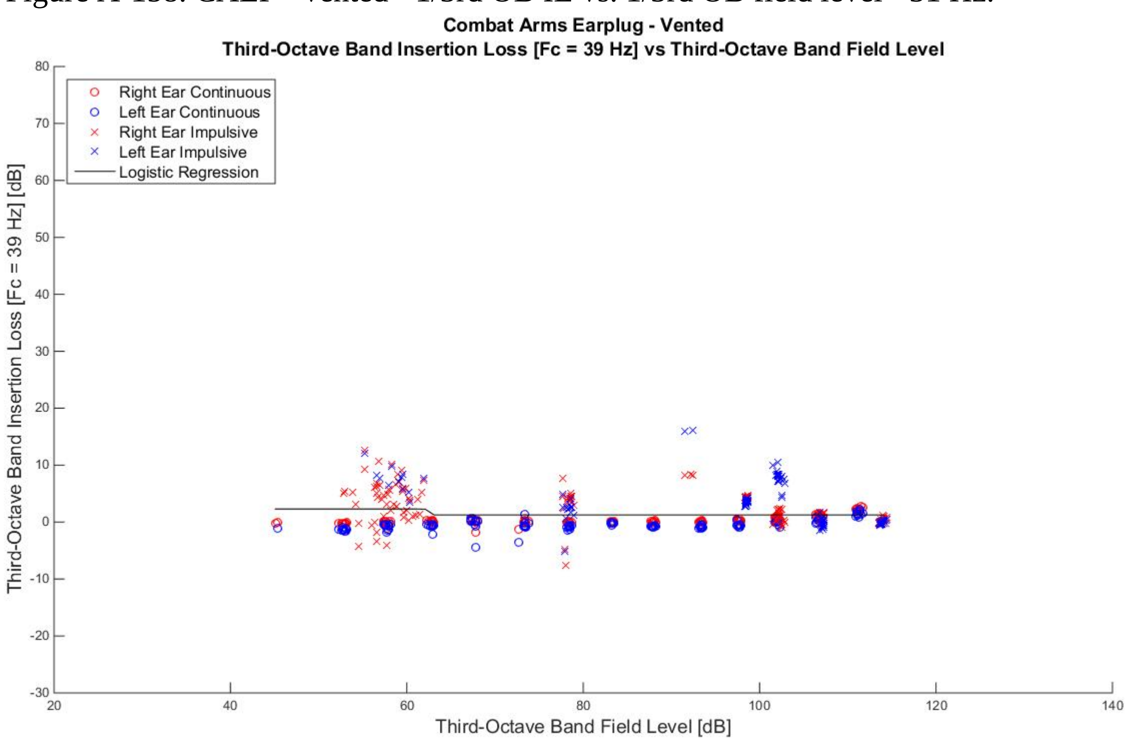

Figure A-159. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

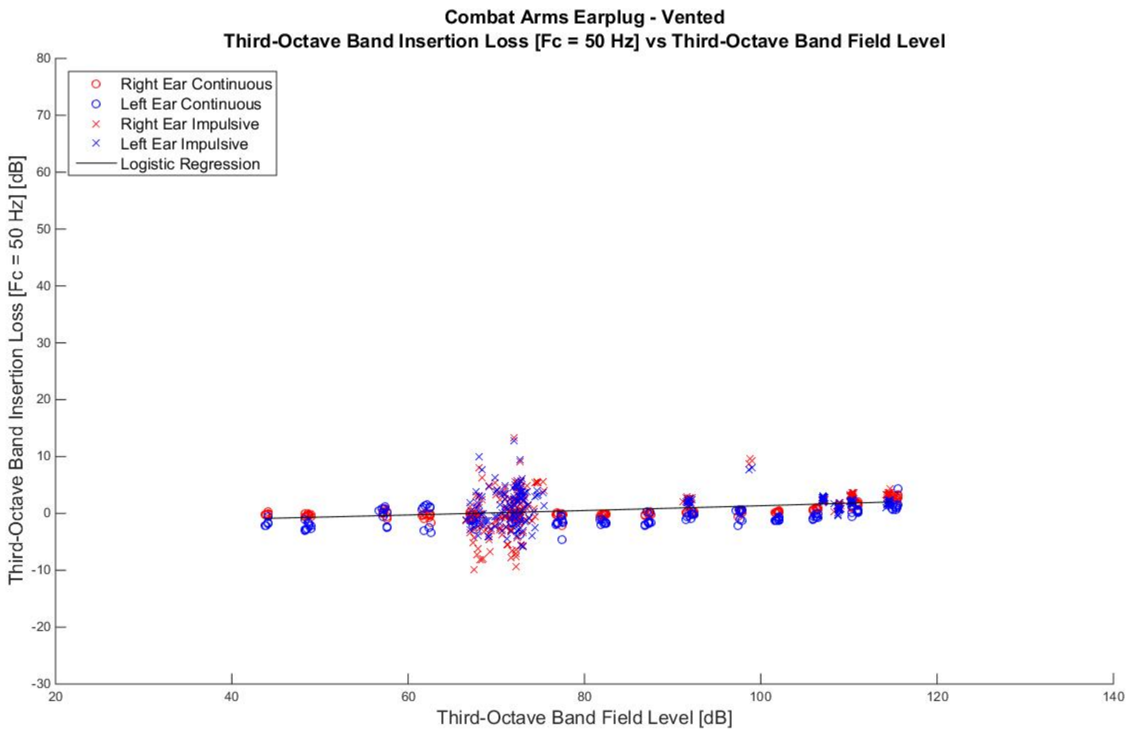

Figure A-160. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

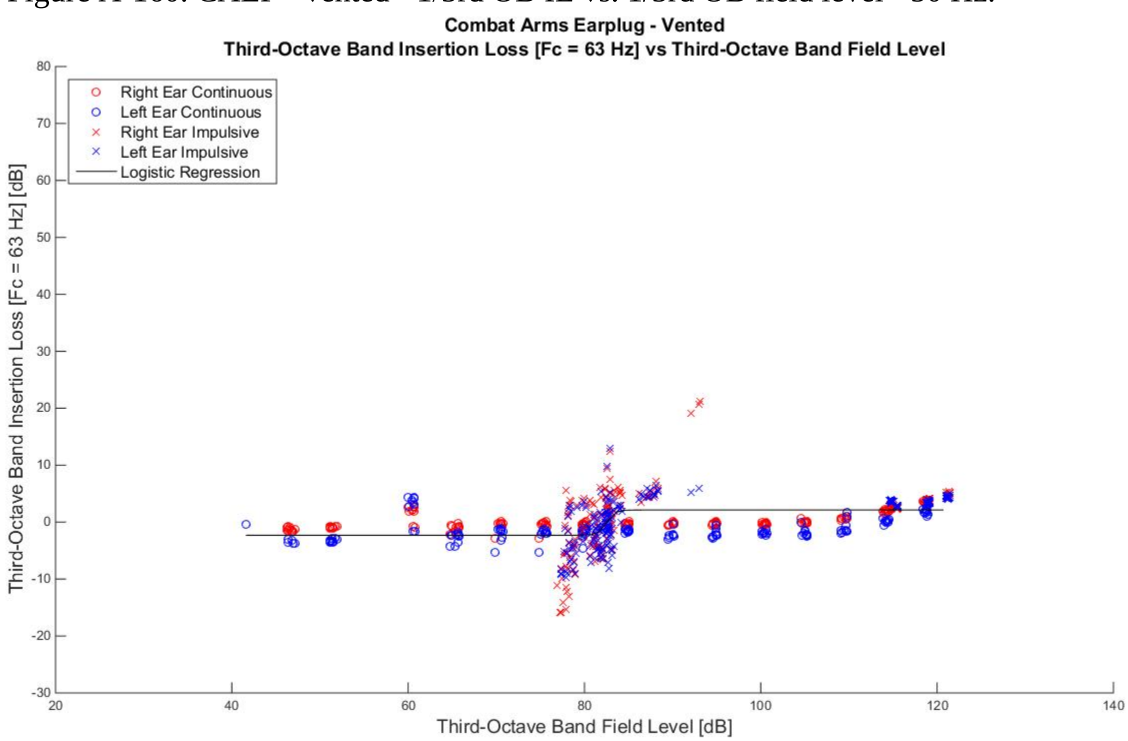

Figure A-161. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

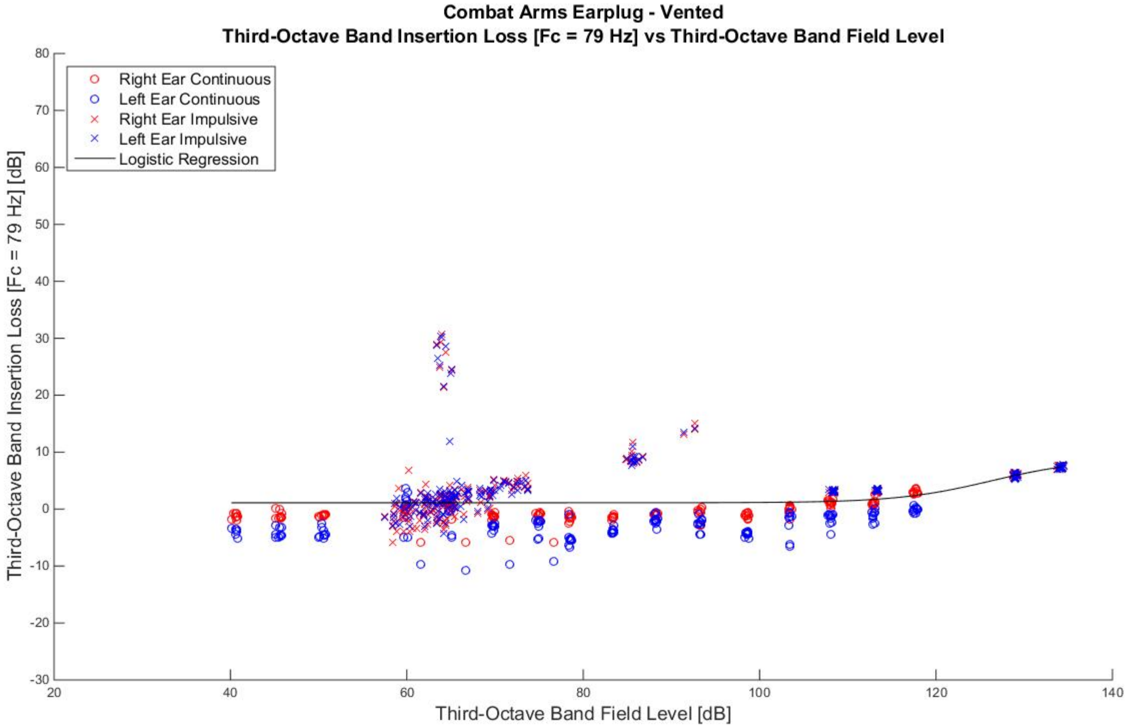

Figure A-162. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

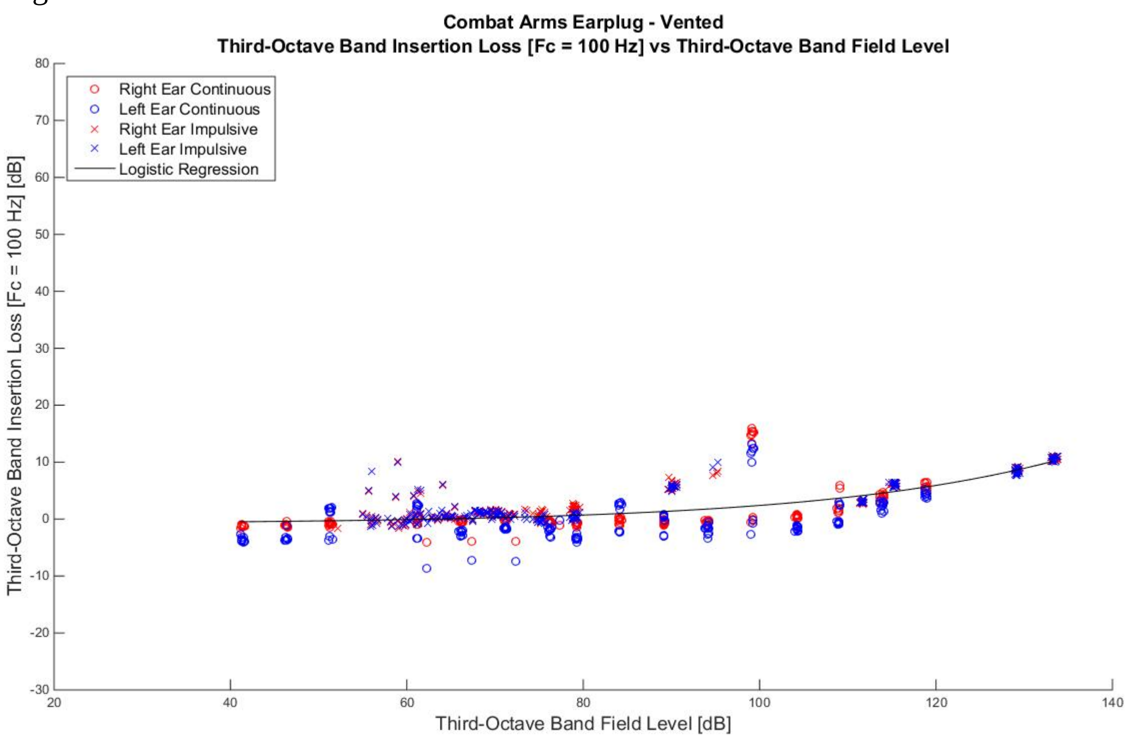

Figure A-163. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

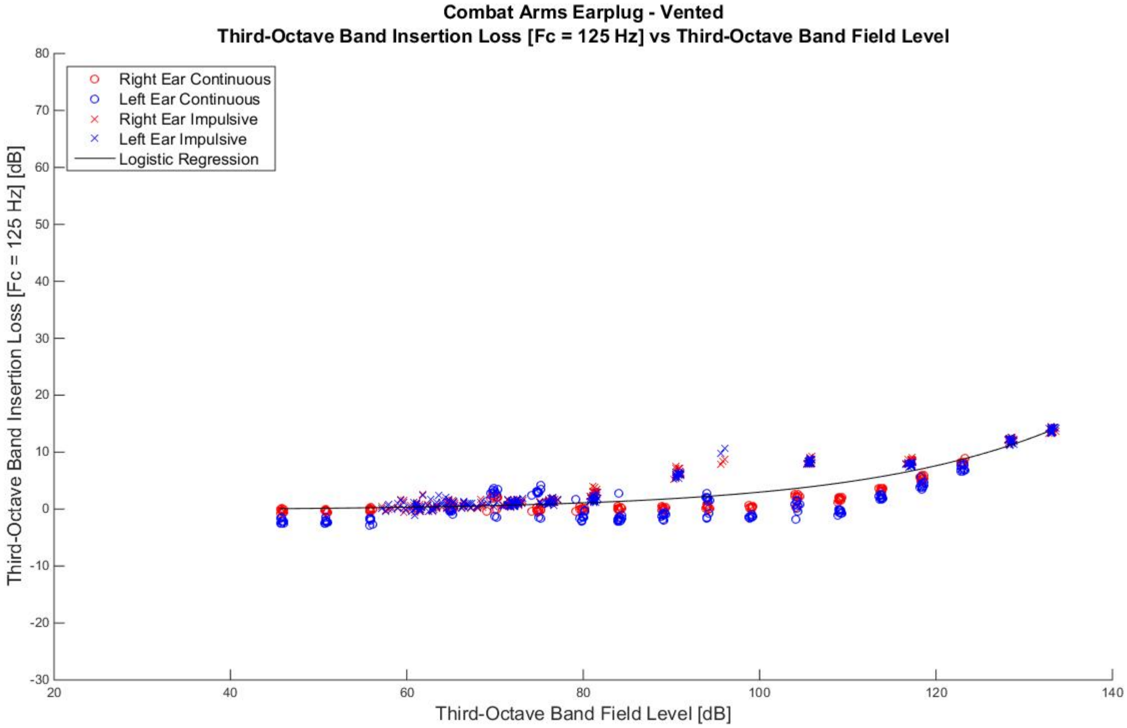

Figure A-164. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

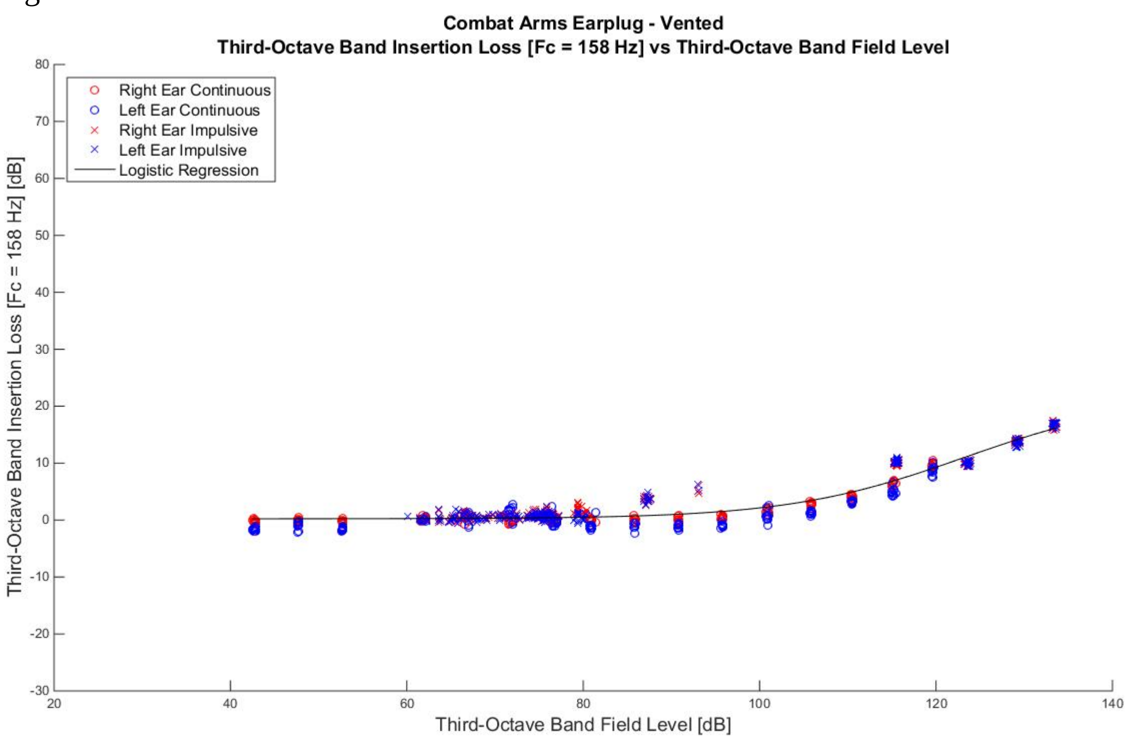

Figure A-165. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

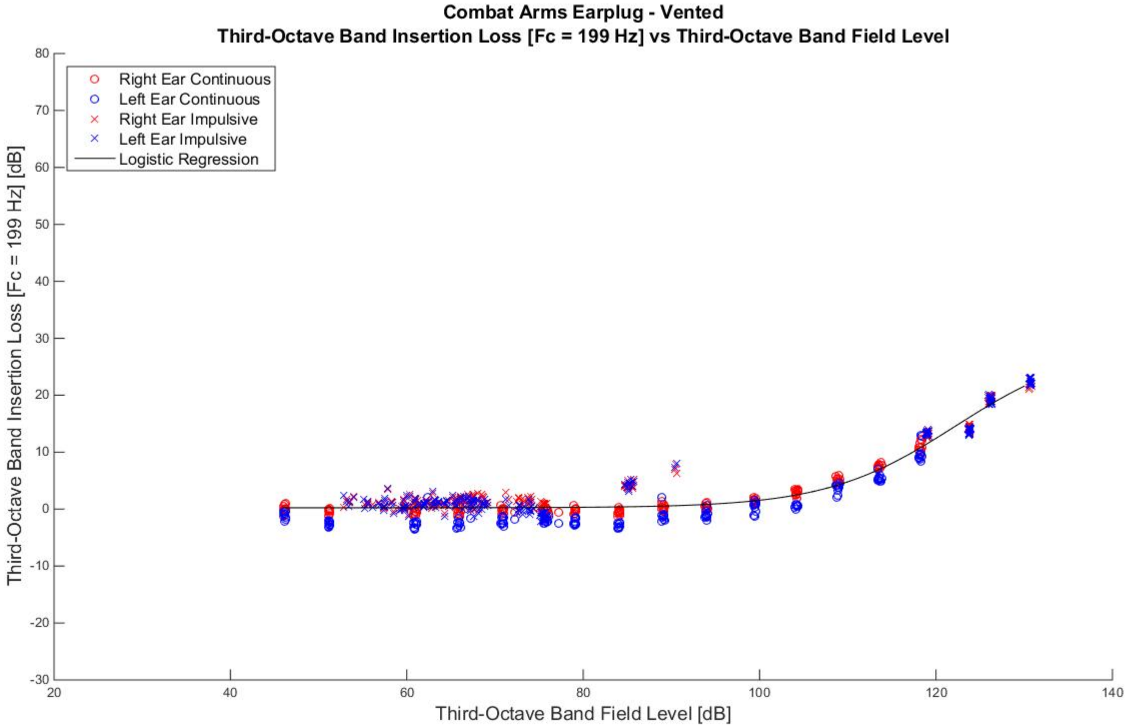

Figure A-166. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

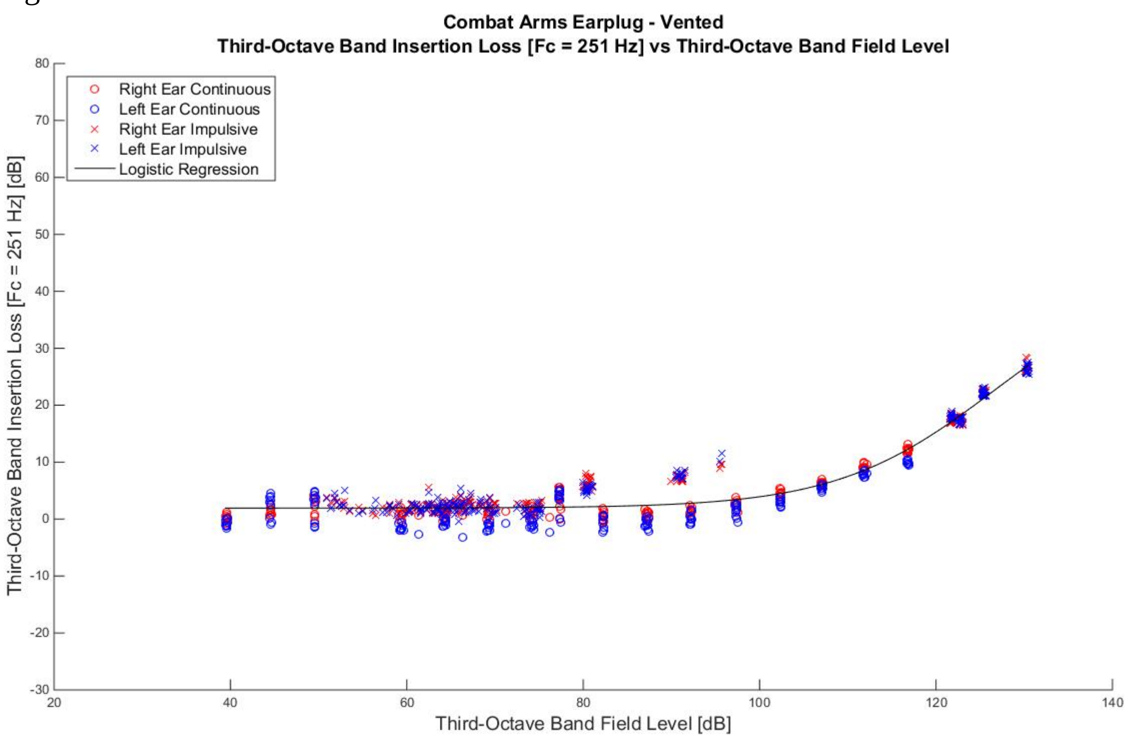

Figure A-167. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

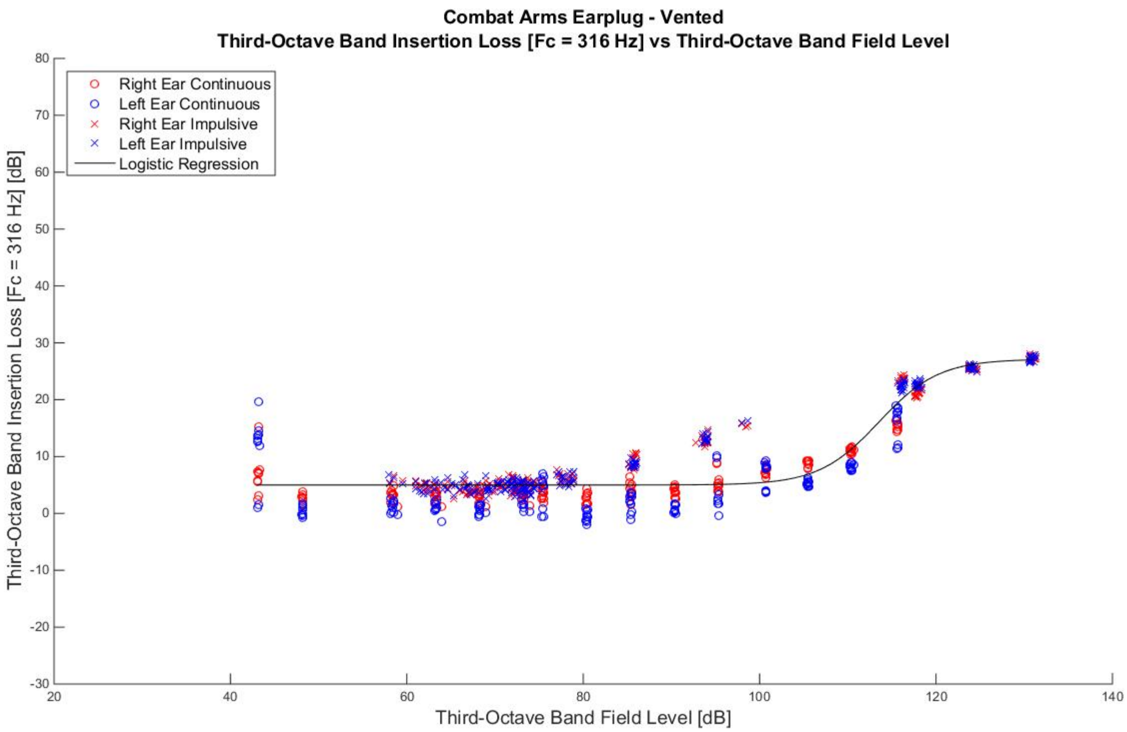

Figure A-168. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

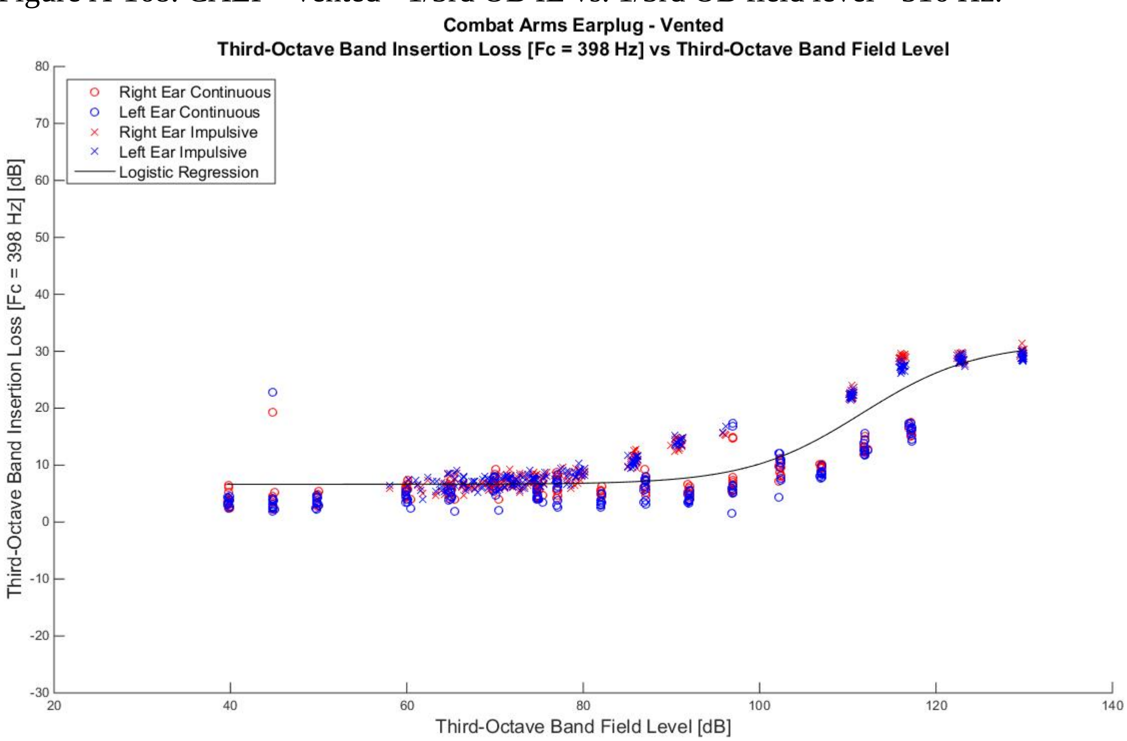

Figure A-169. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

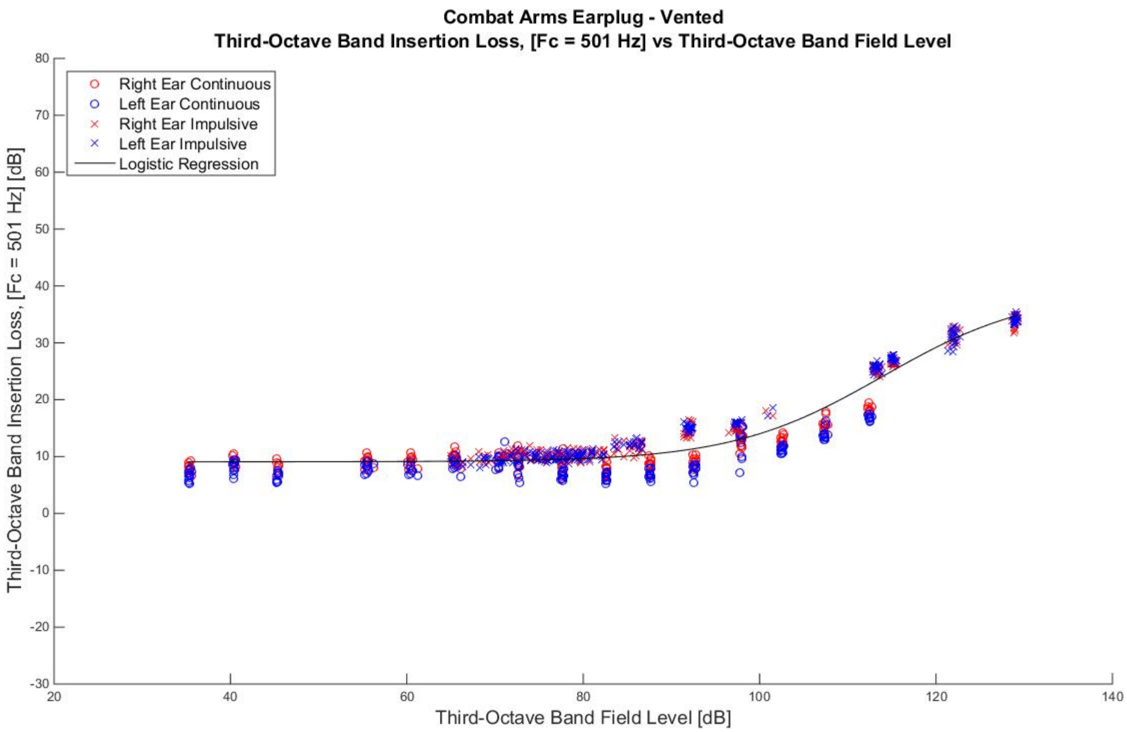

Figure A-170. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

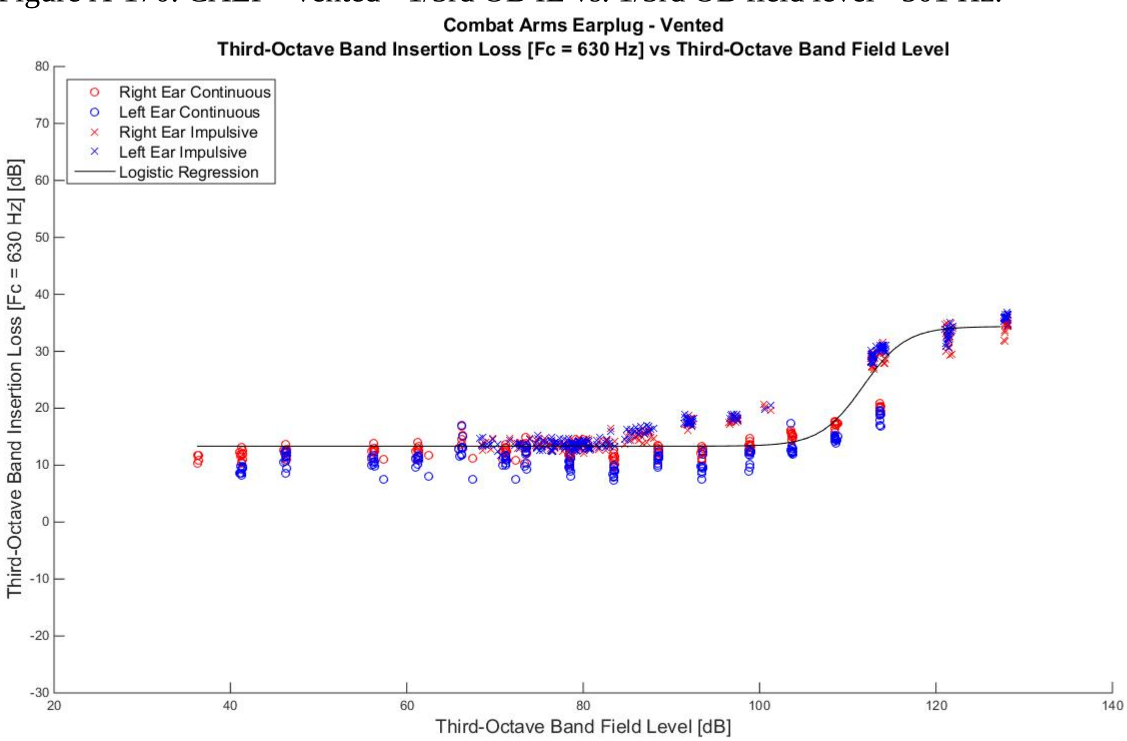

Figure A-171. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

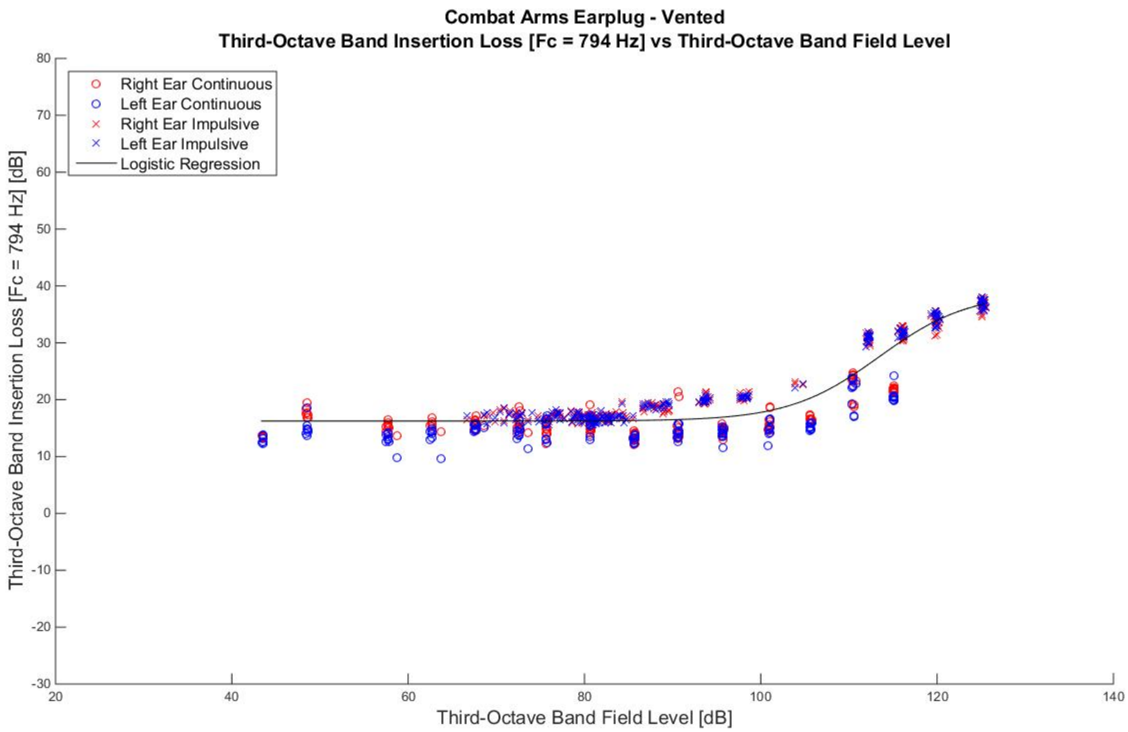

Figure A-172. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

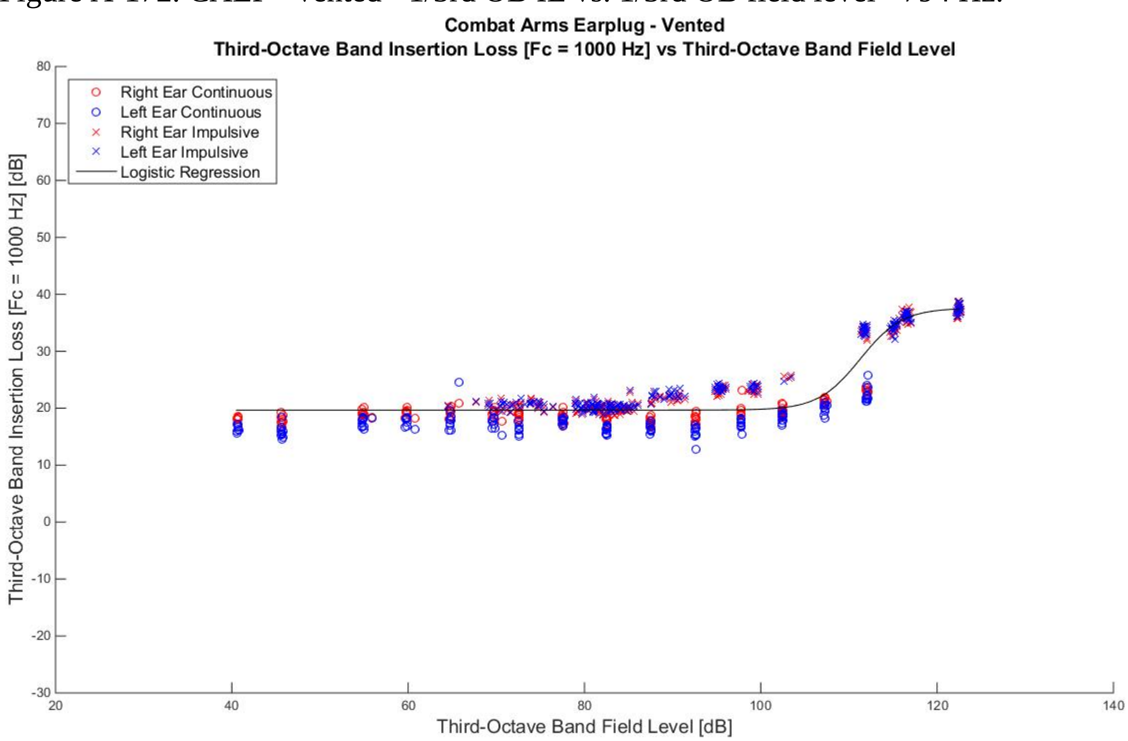

Figure A-173. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

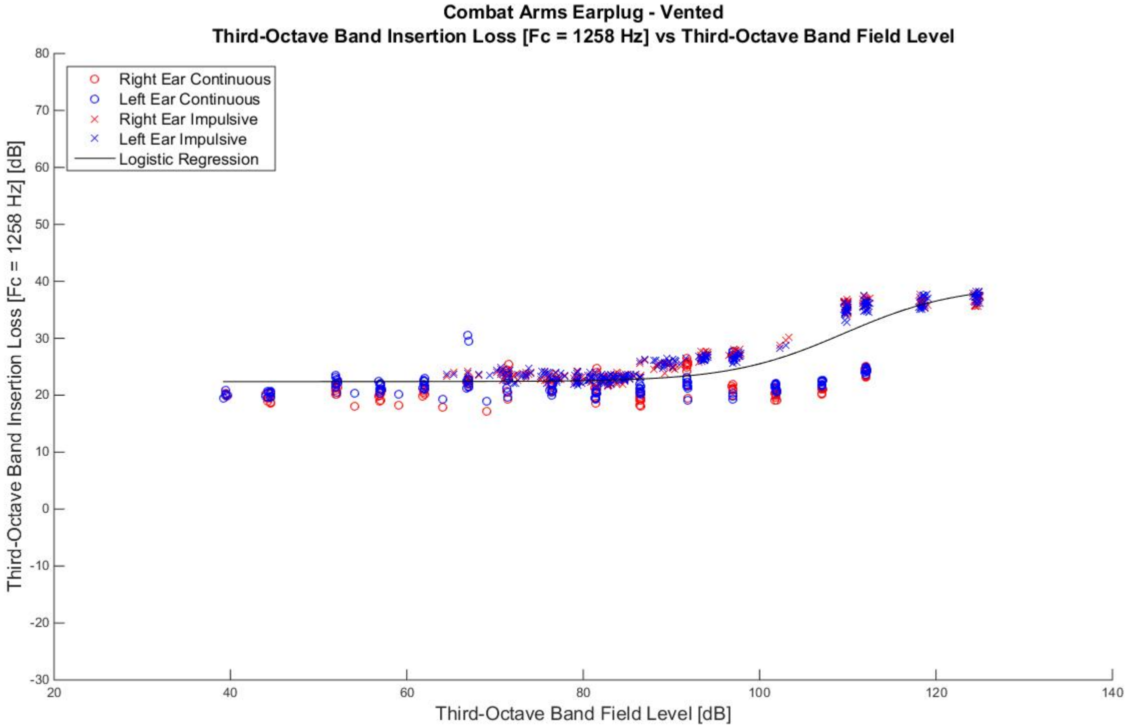

Figure A-174. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

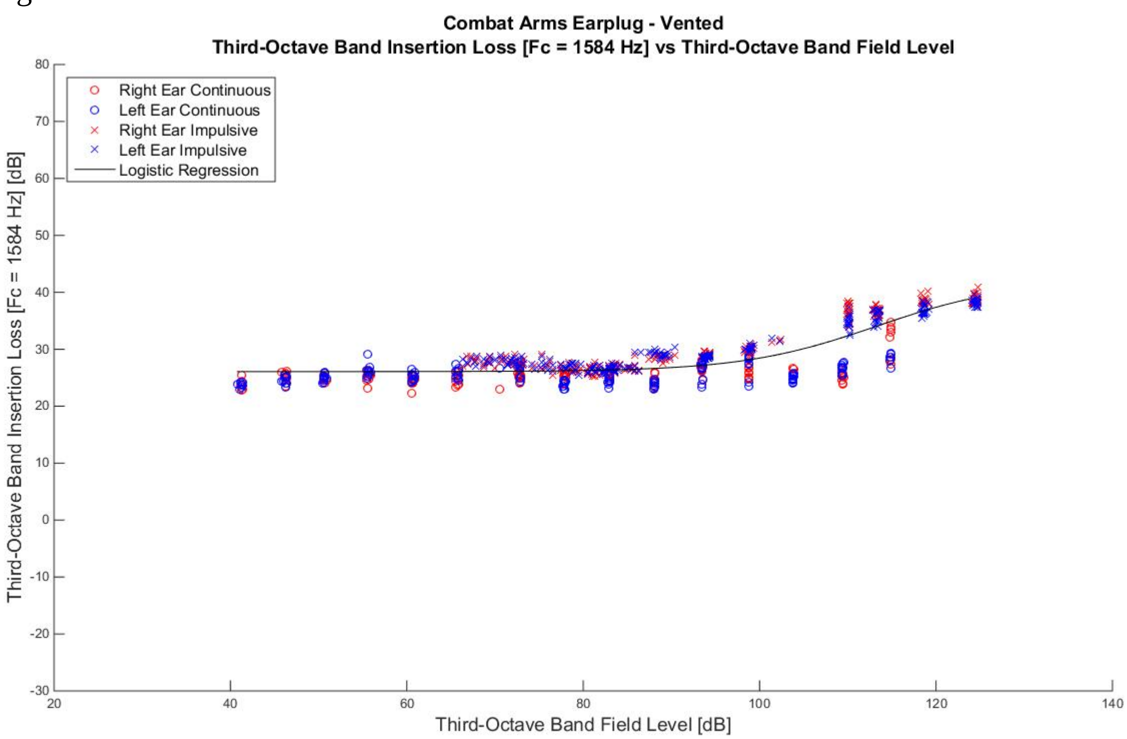

Figure A-175. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

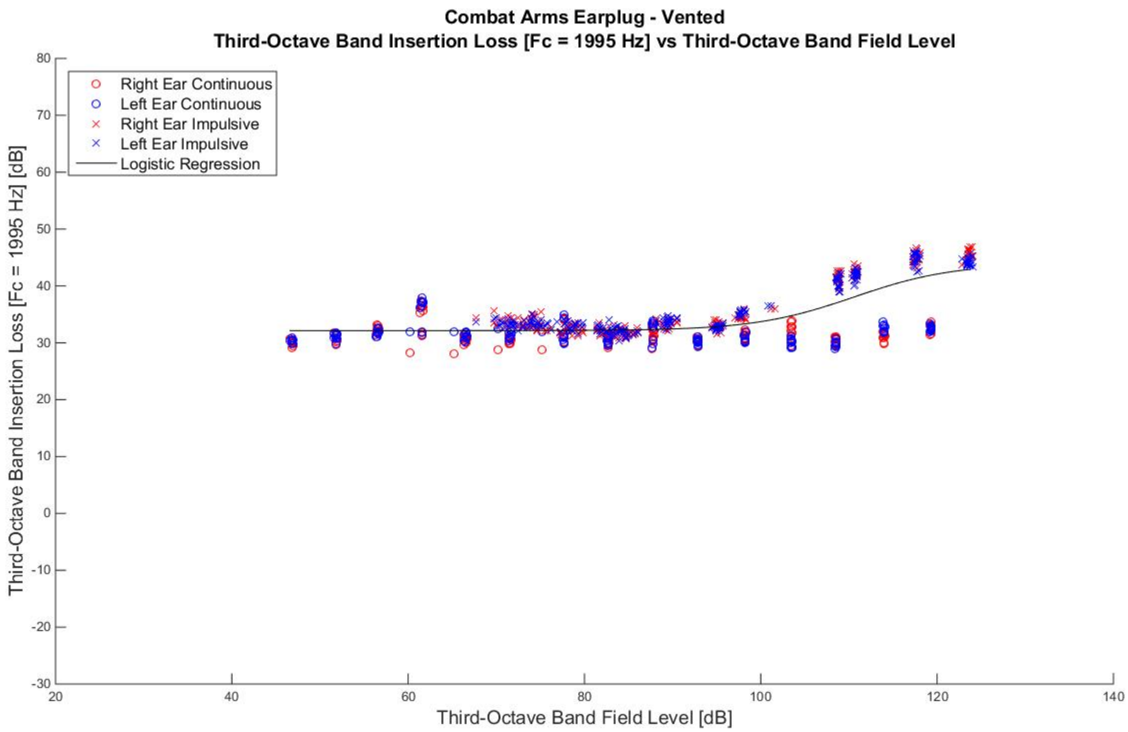

Figure A-176. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

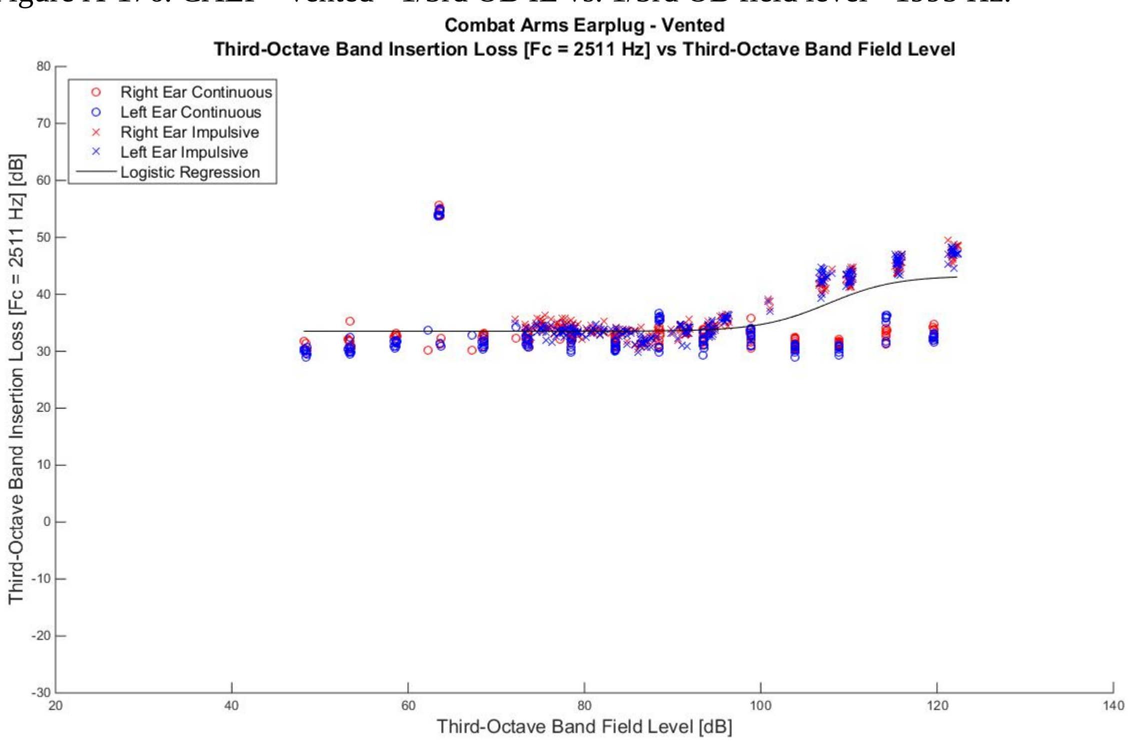

Figure A-177. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

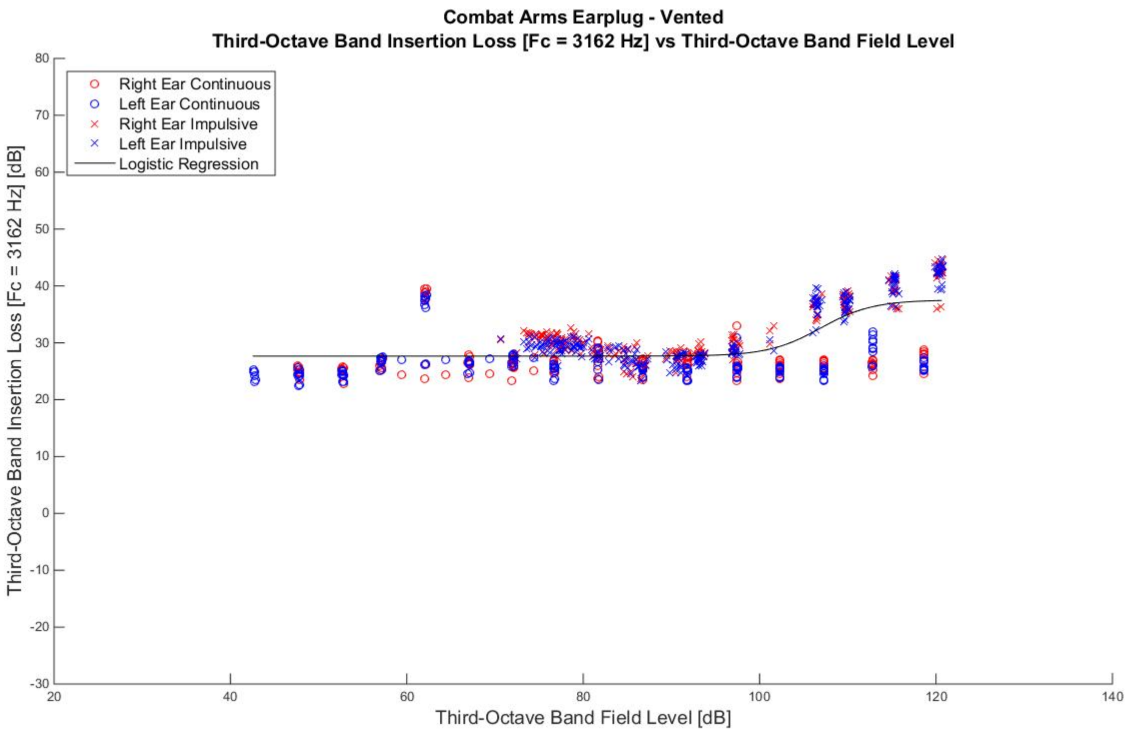

Figure A-178. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

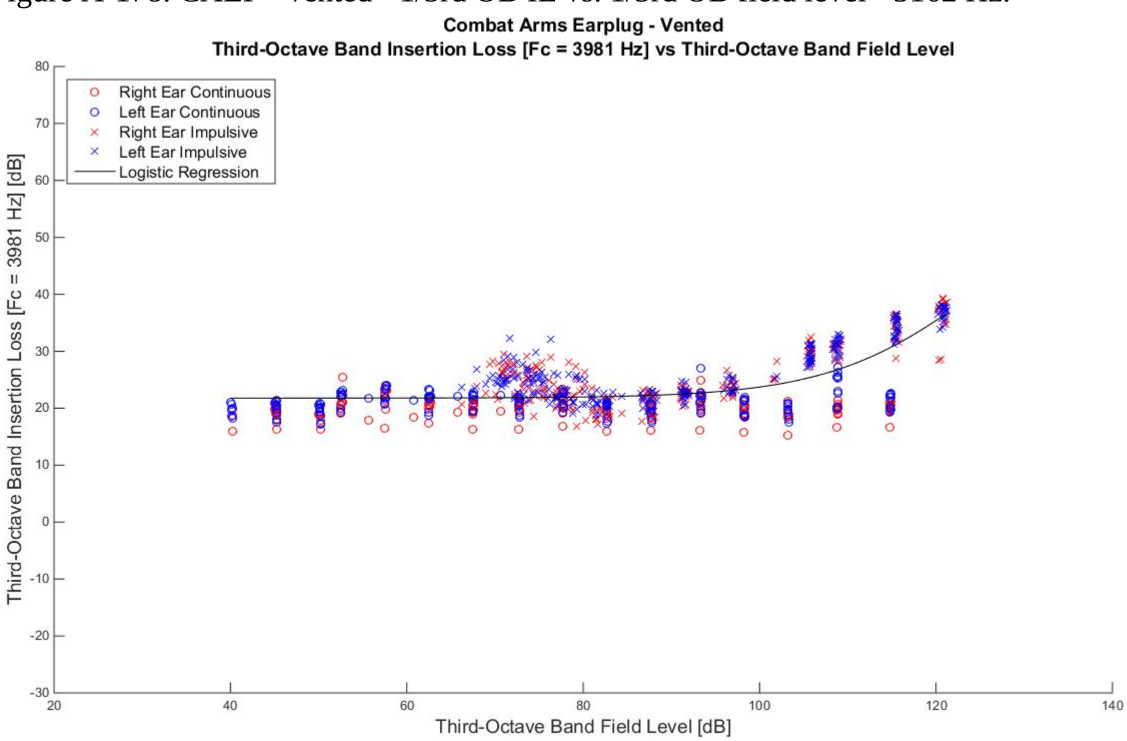

Figure A-179. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

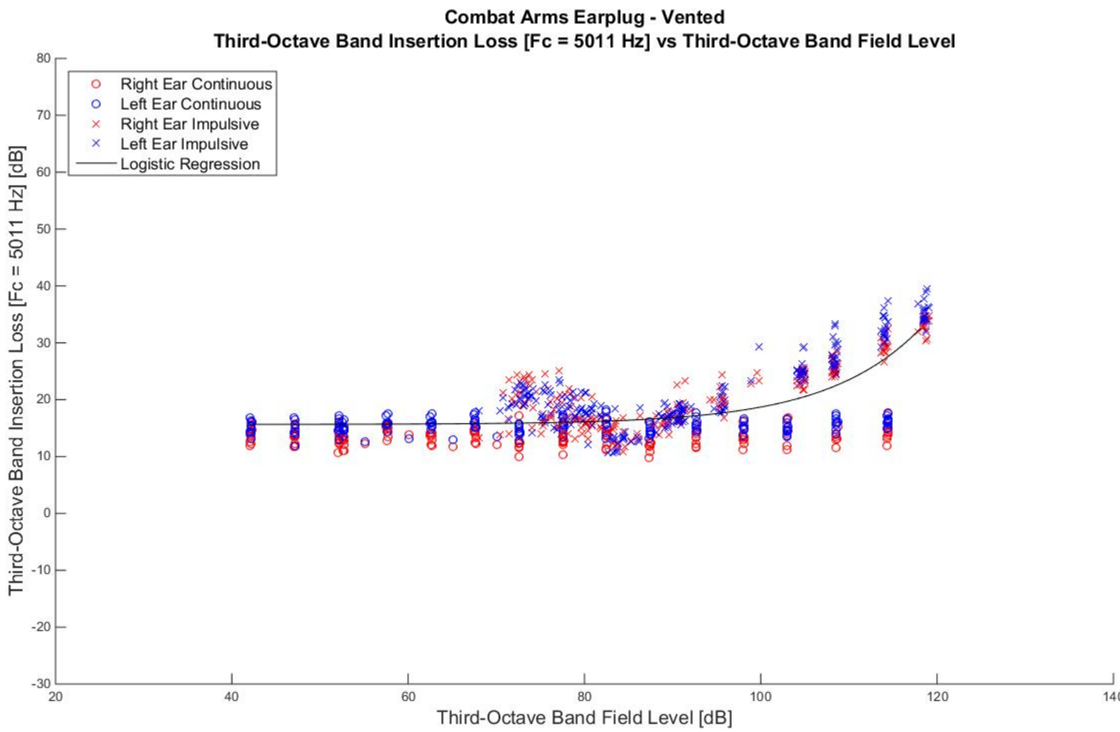

Figure A-180. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

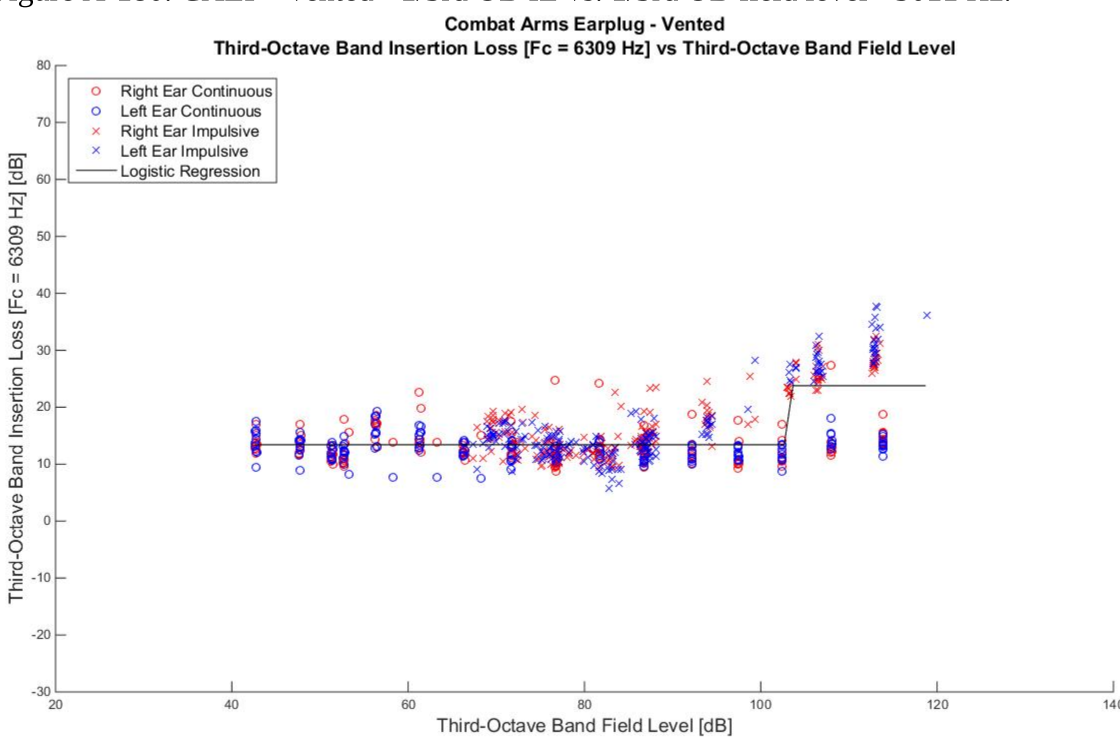

Figure A-181. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

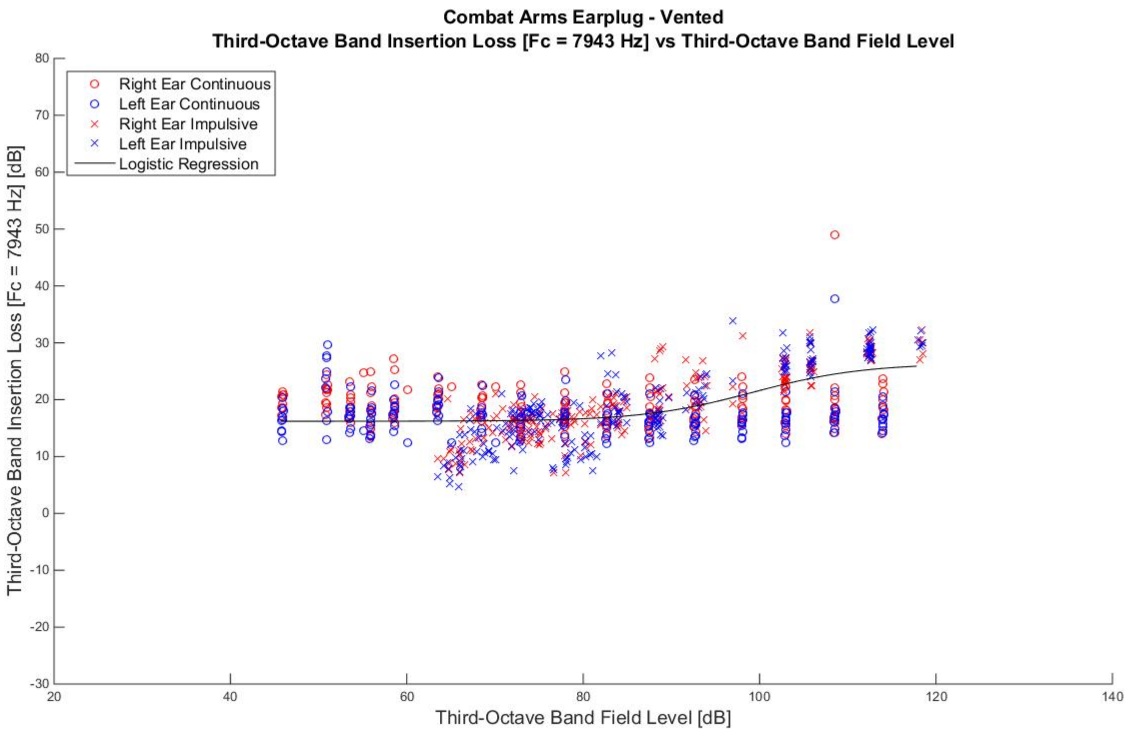

Figure A-182. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

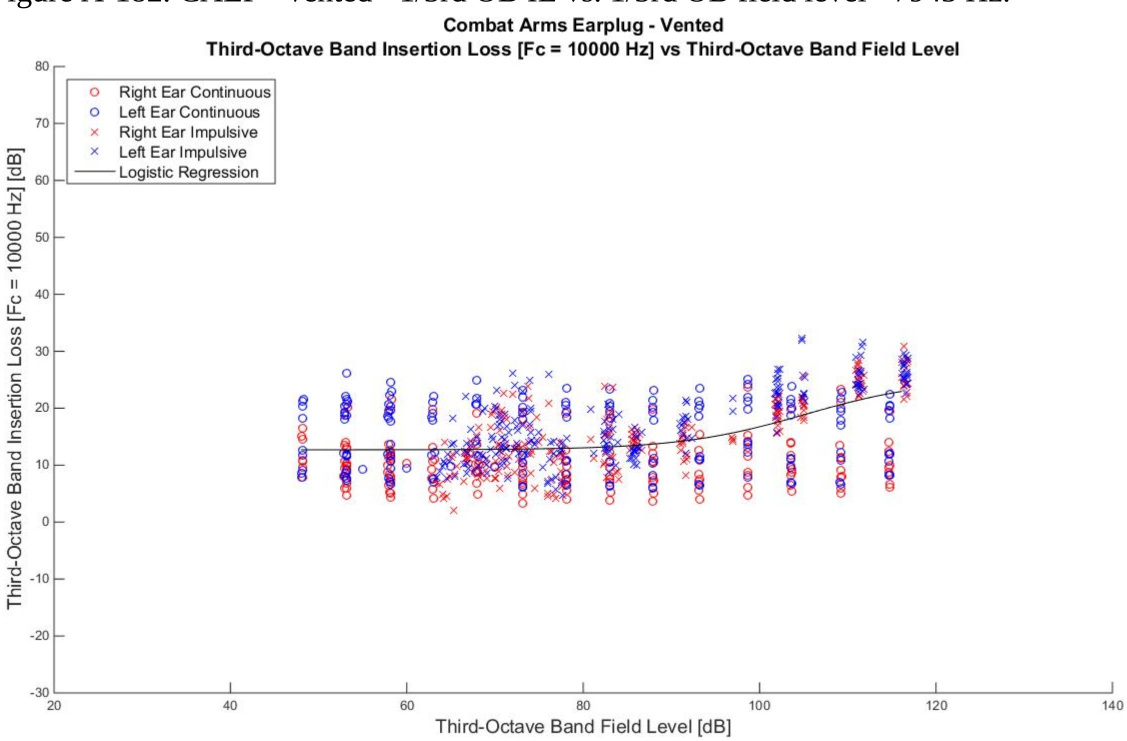

Figure A-183. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

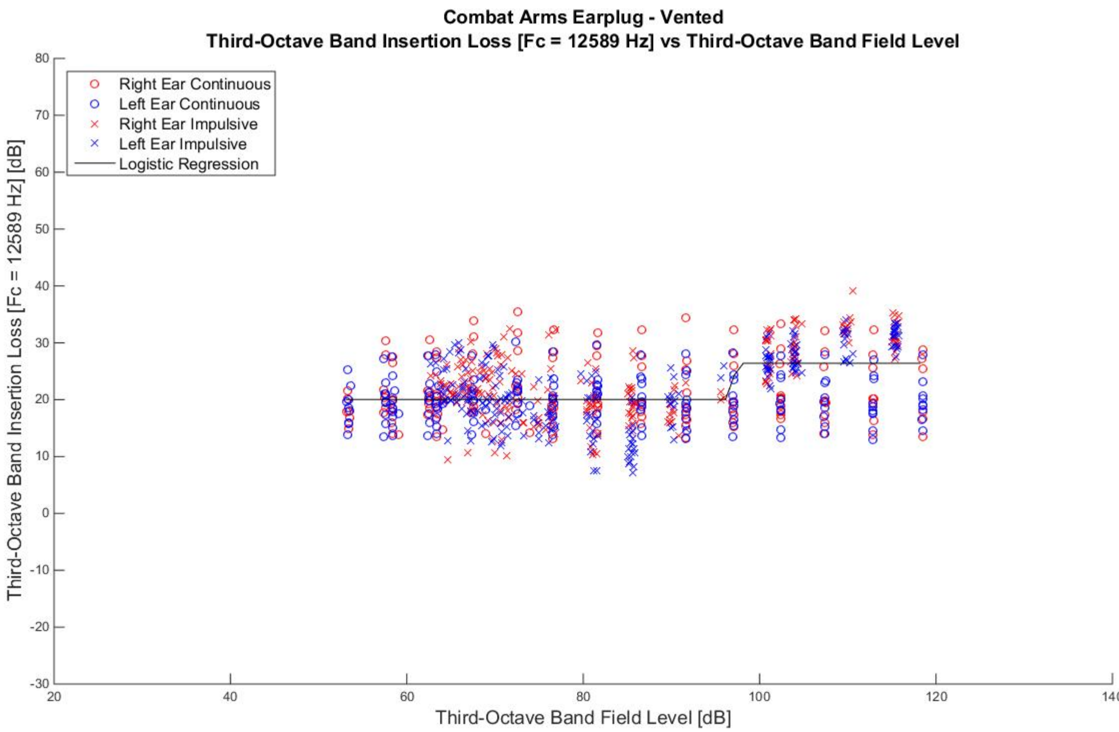

Figure A-184. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

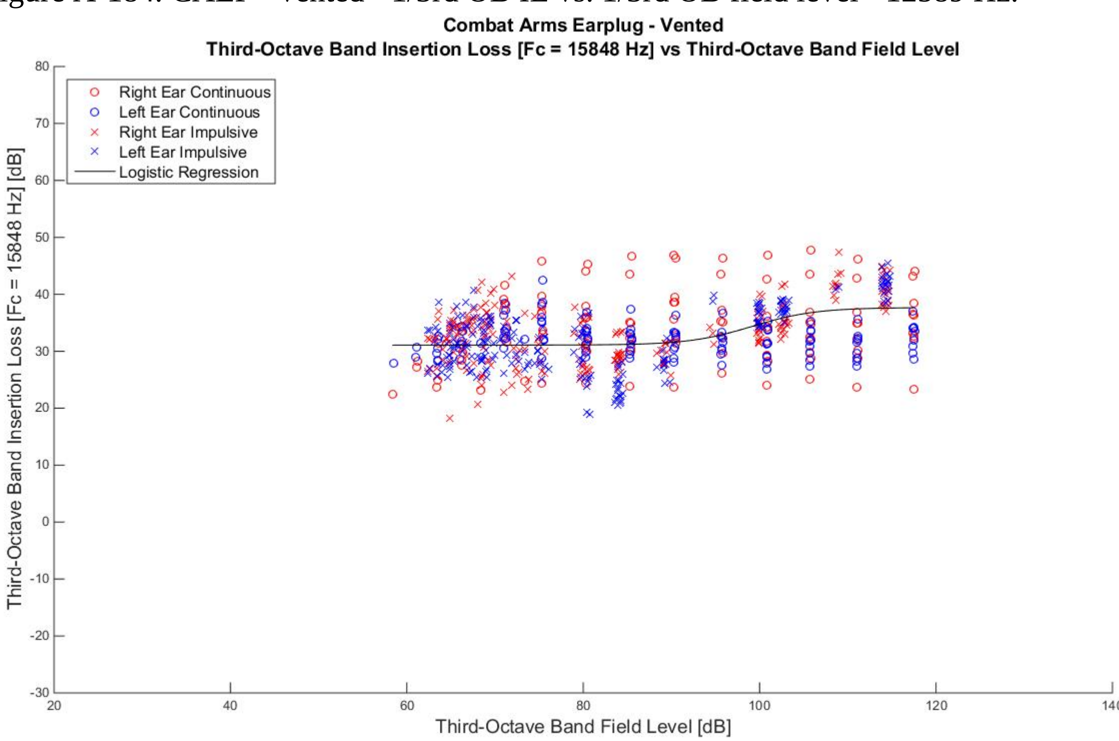

Figure A-185. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

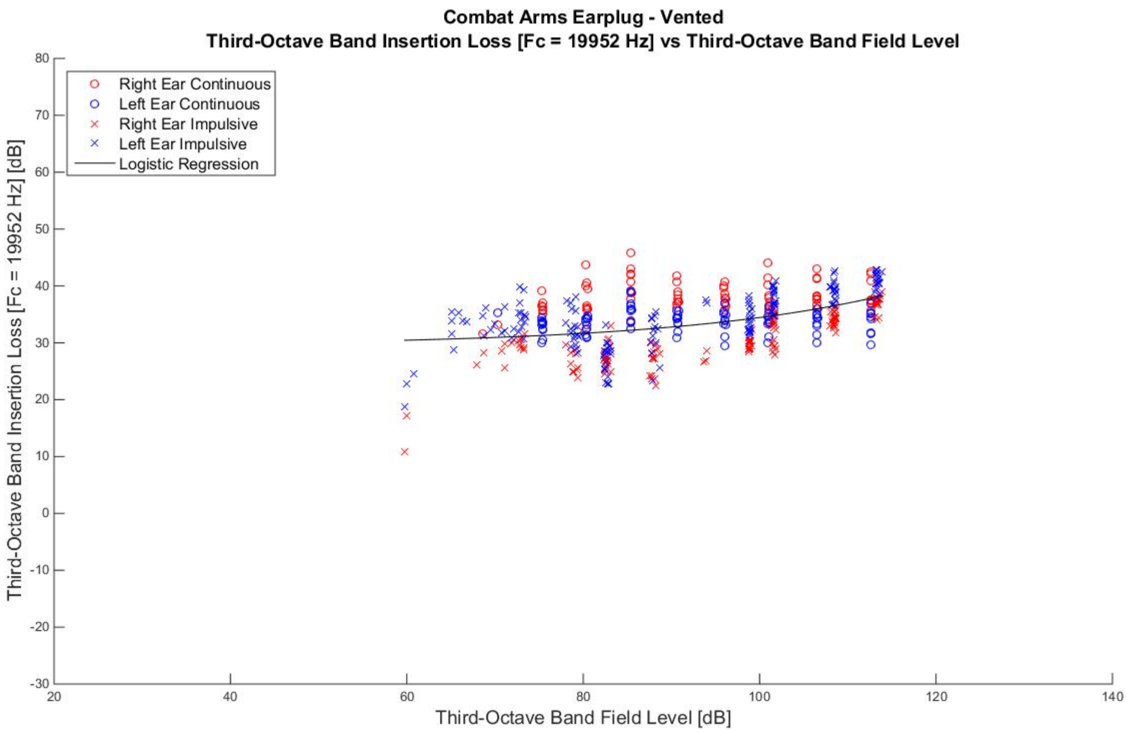

Figure A-186. CAEP - vented - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

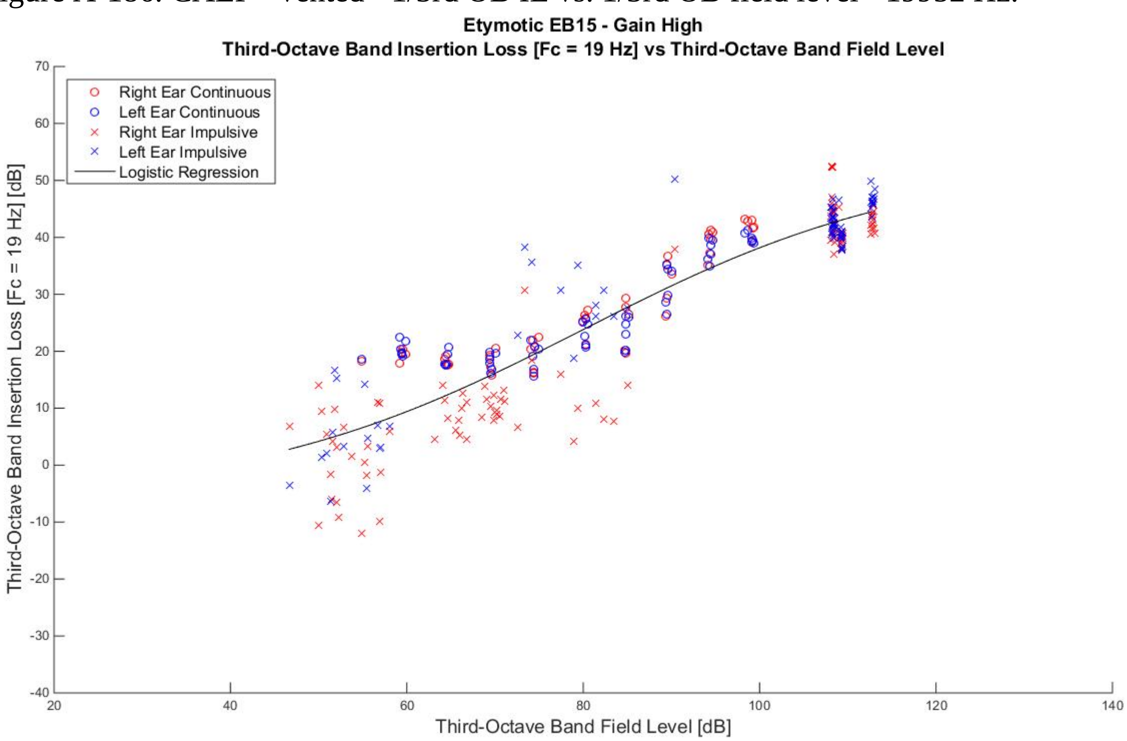

Figure A-187. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

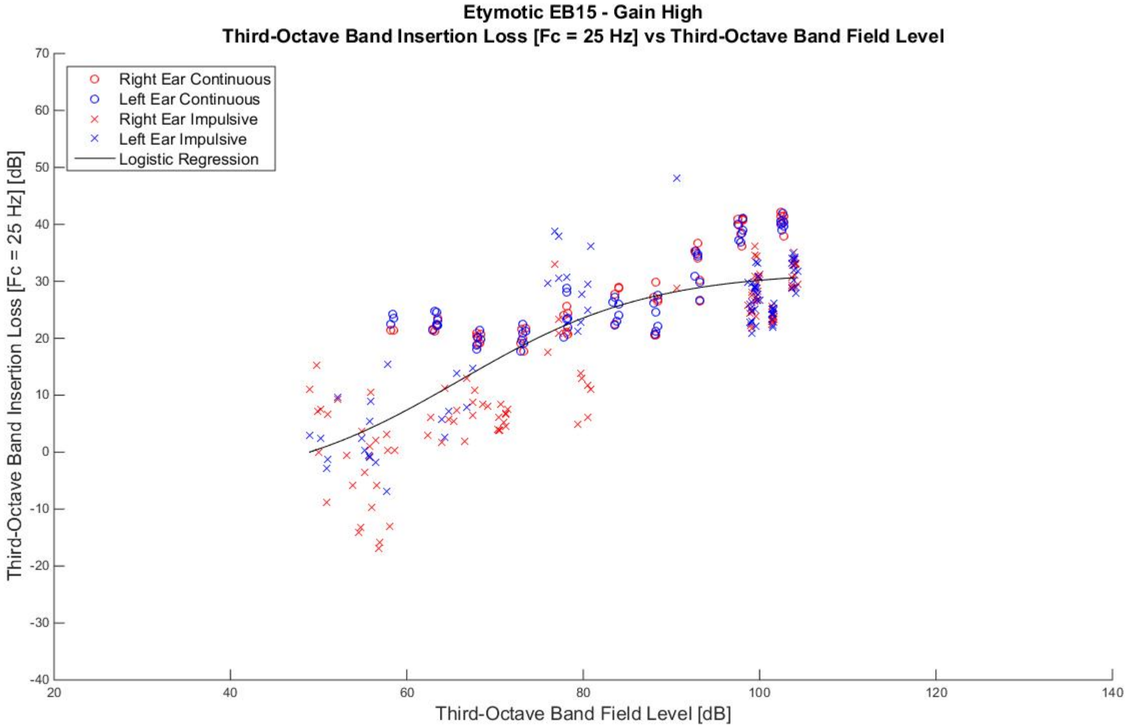

Figure A-188. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

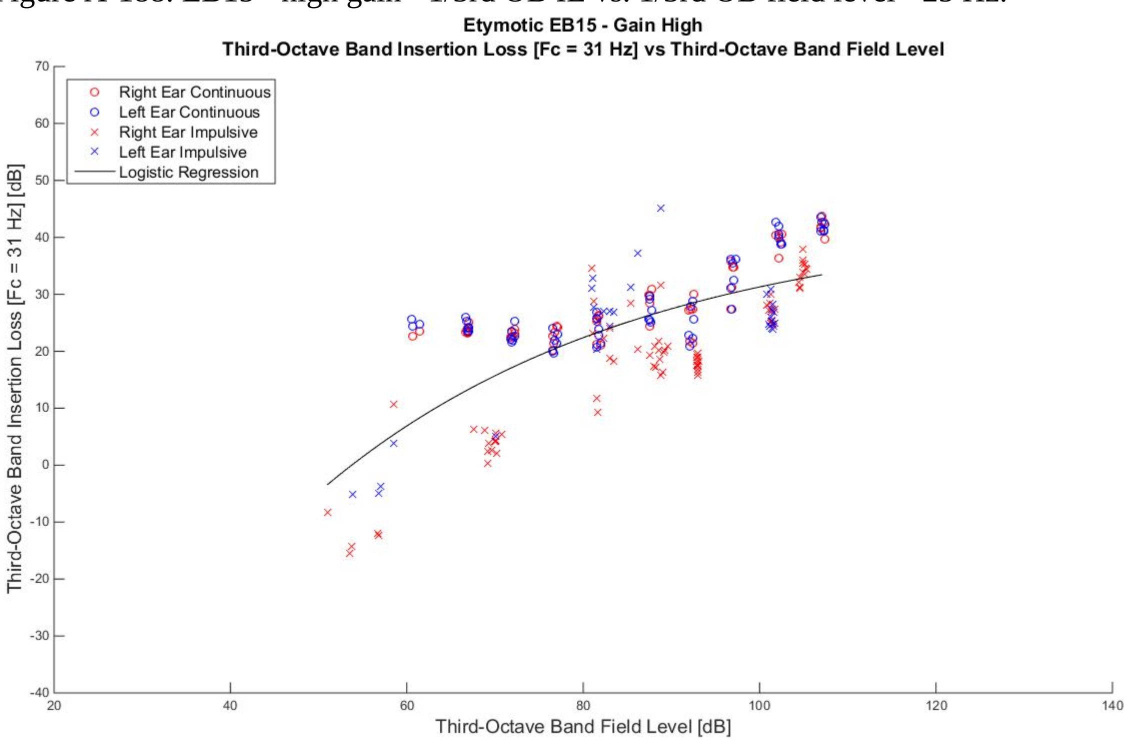

Figure A-189. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

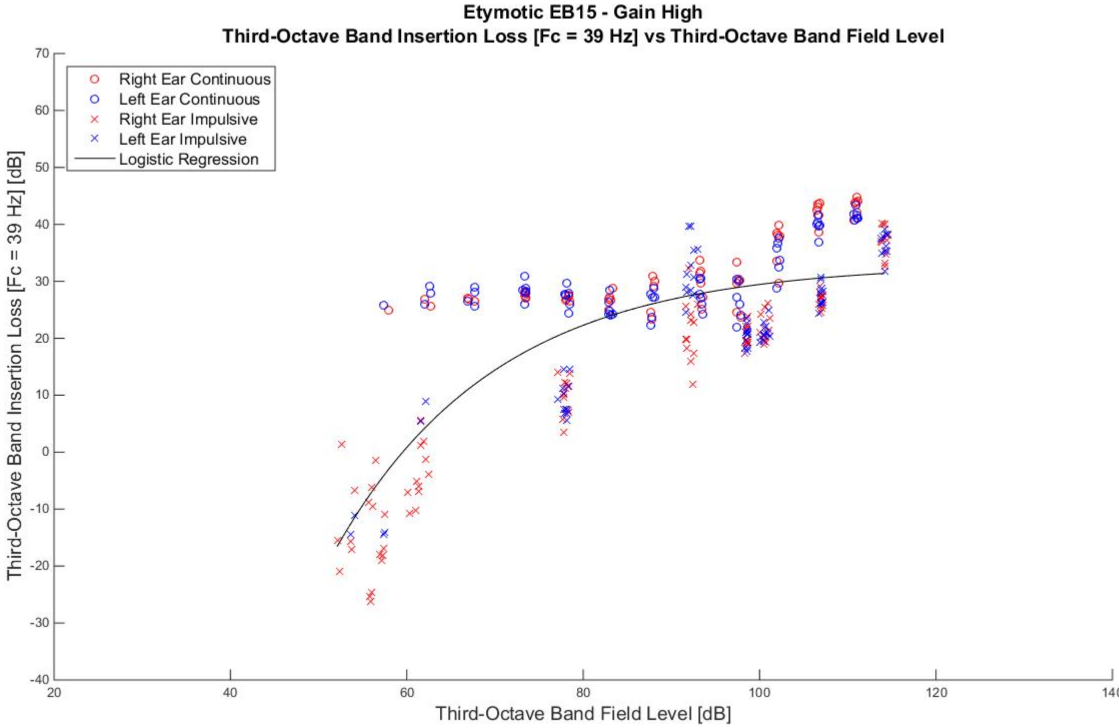

Figure A-190. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

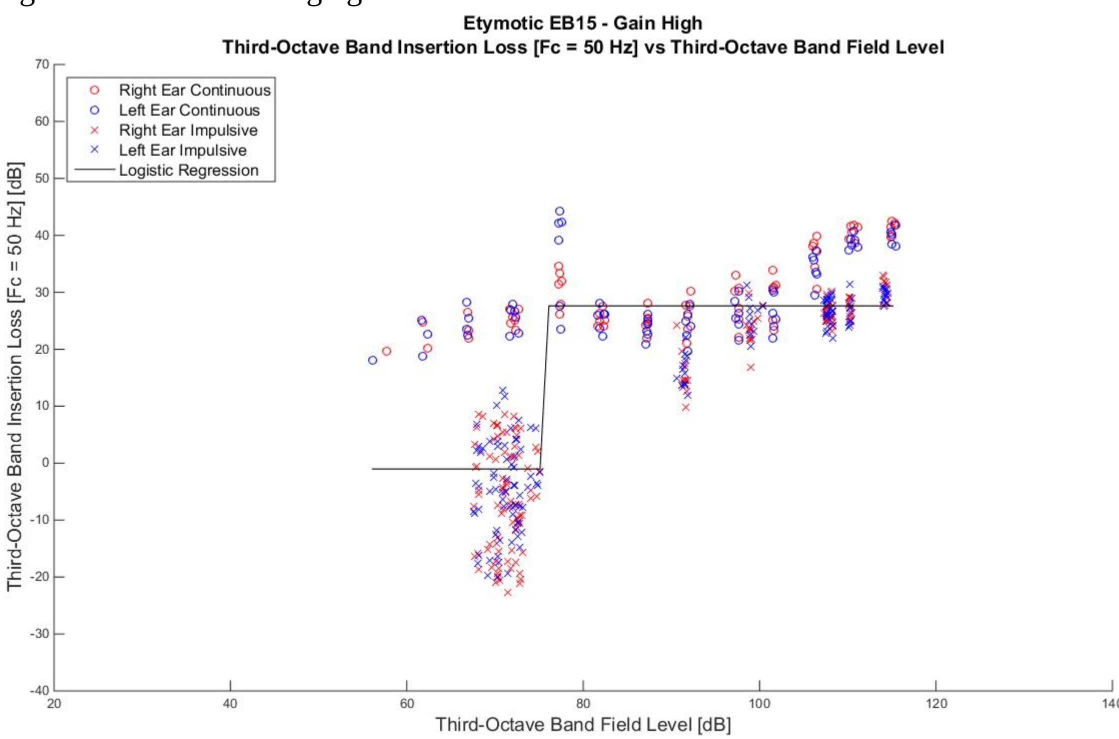

Figure A-191. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

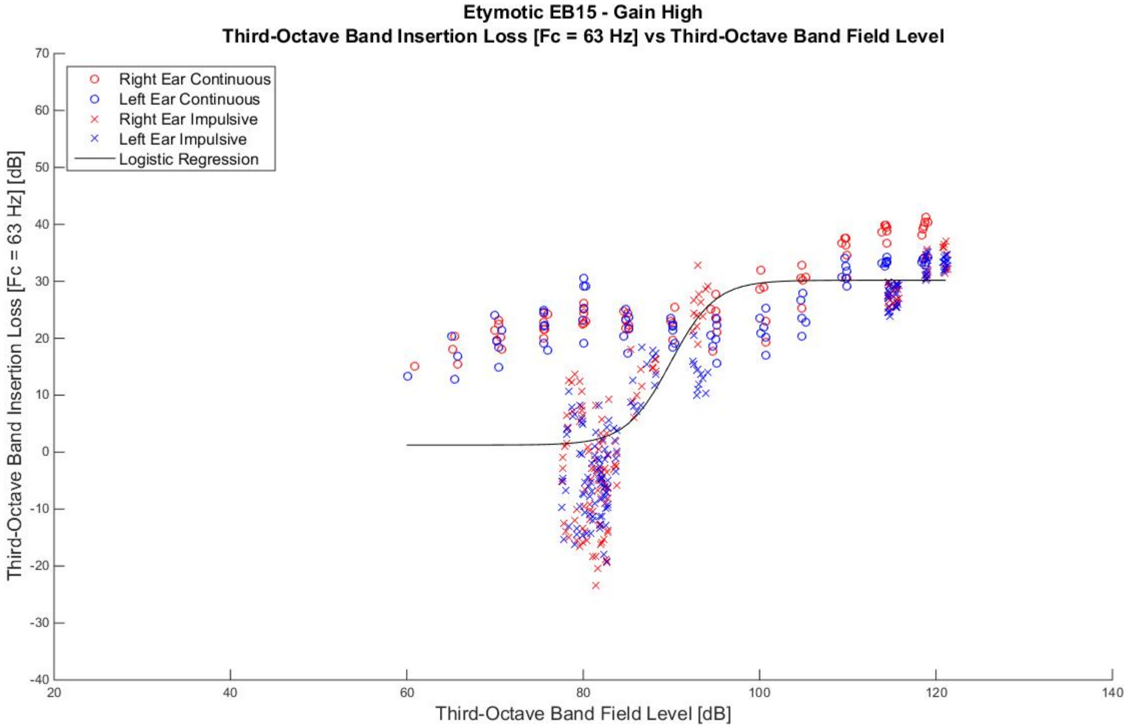

Figure A-192. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

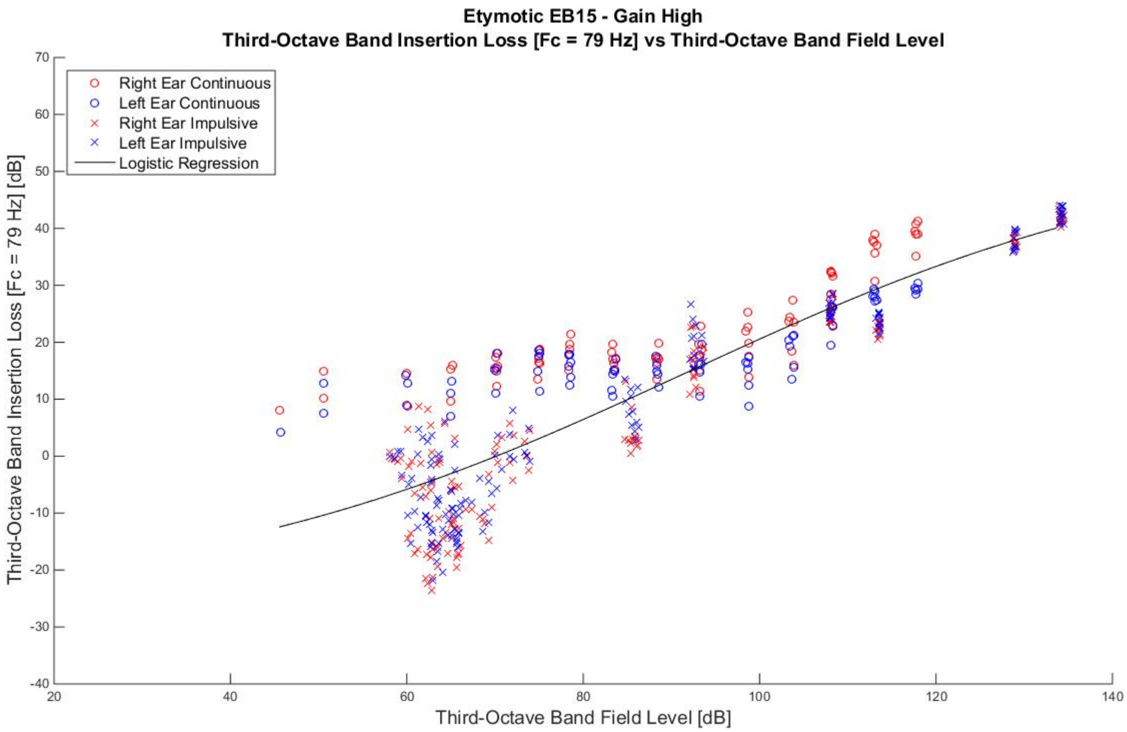

Figure A-193. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

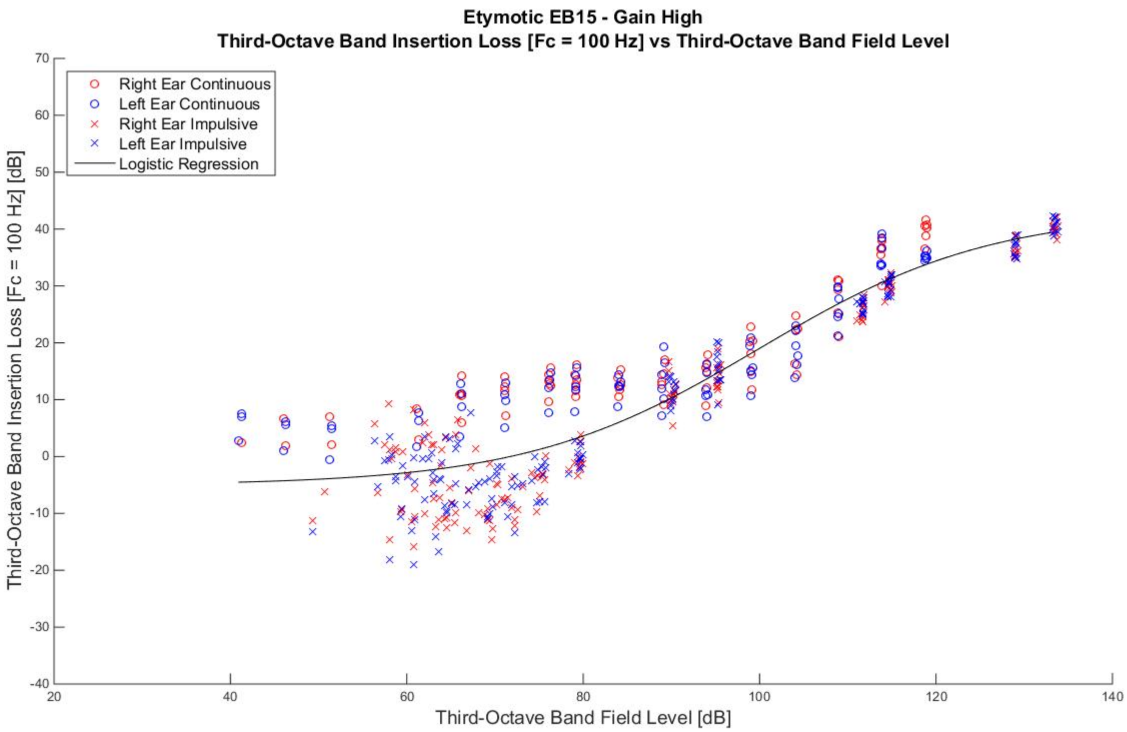

Figure A-194. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

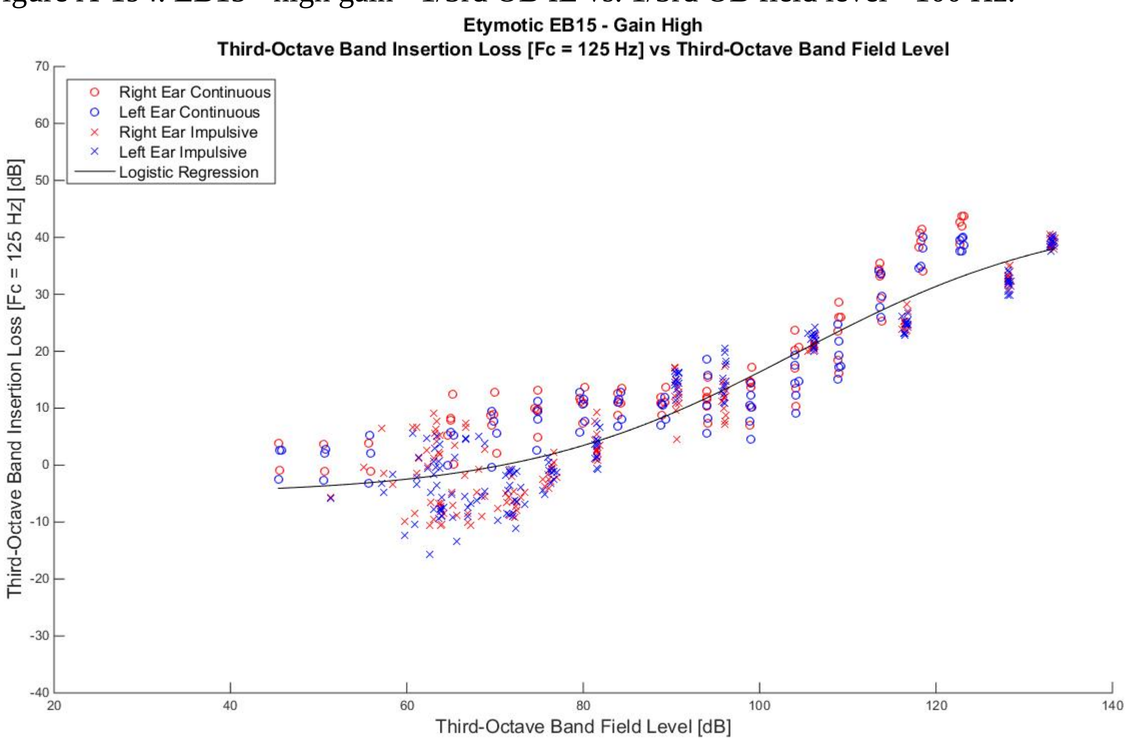

Figure A-195. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

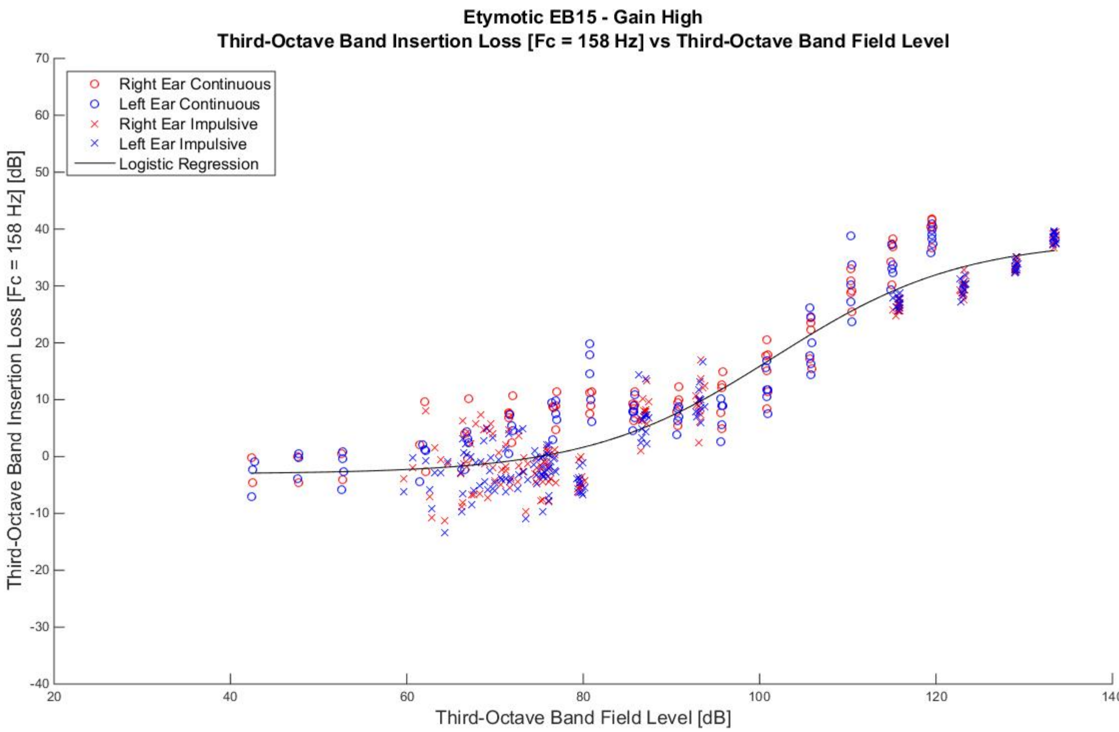

Figure A-196. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

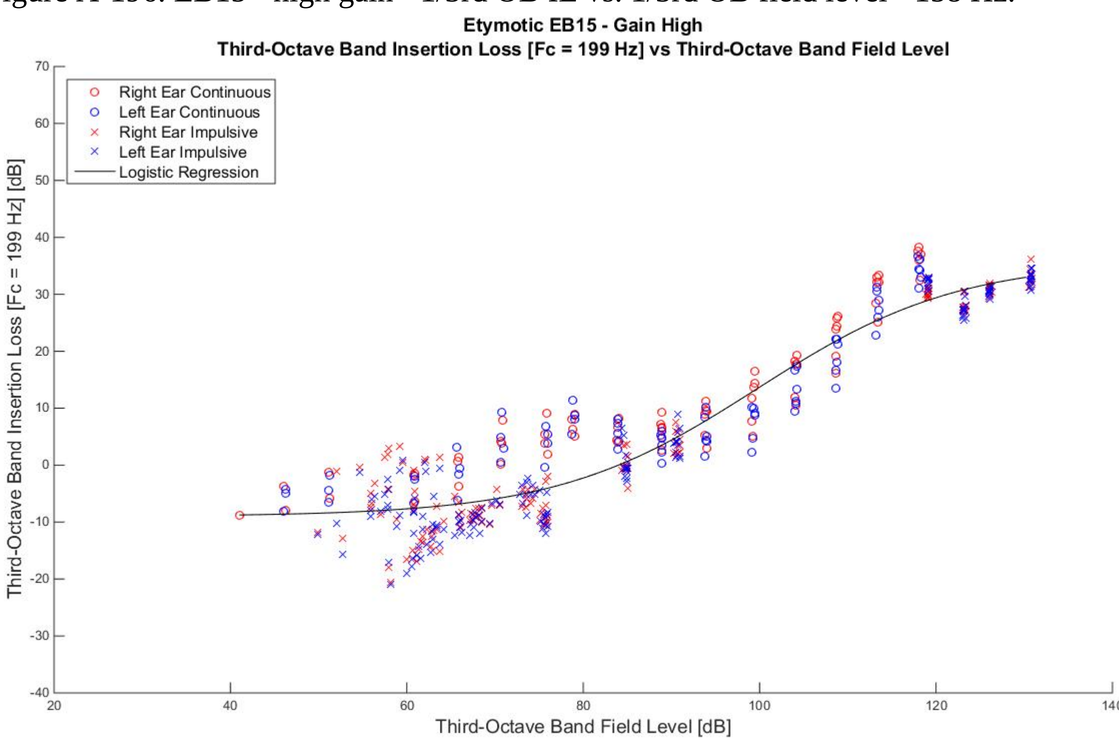

Figure A-197. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

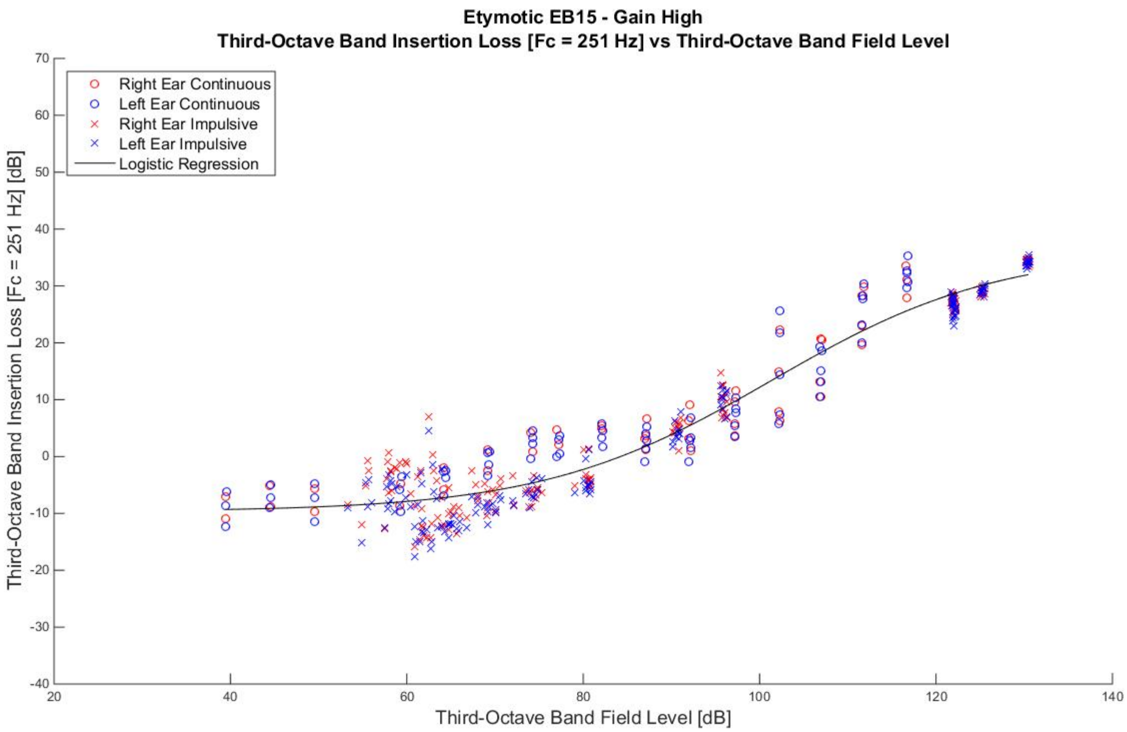

Figure A-198. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

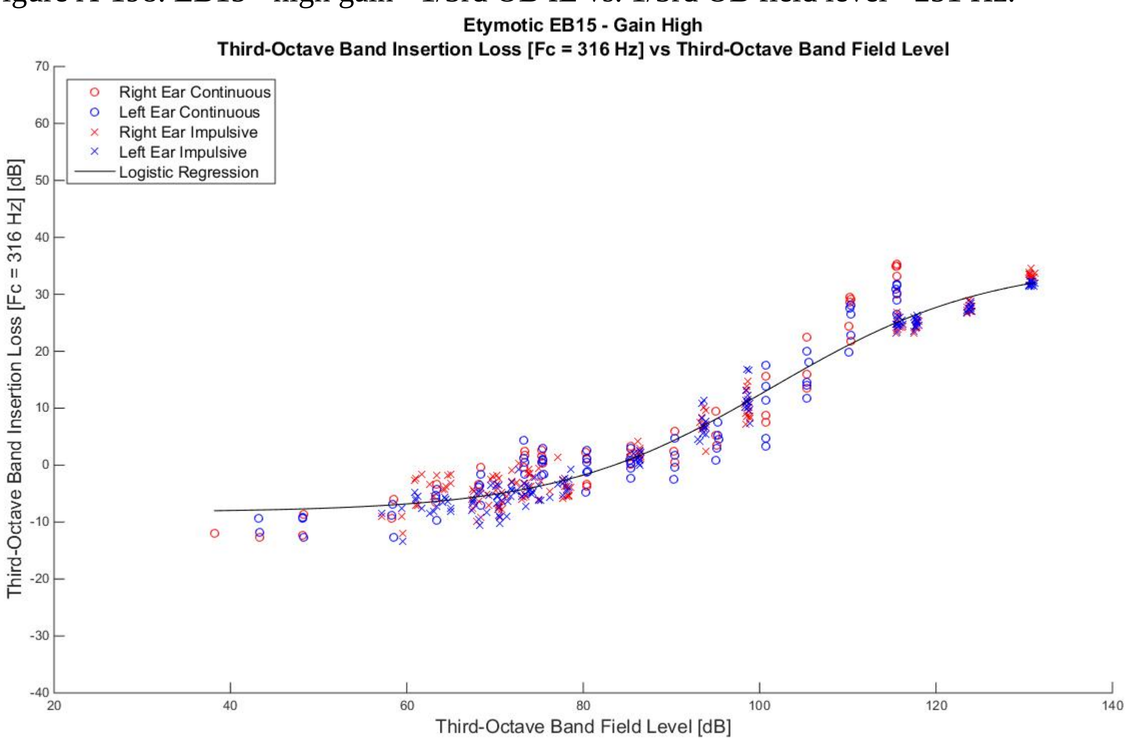

Figure A-199. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

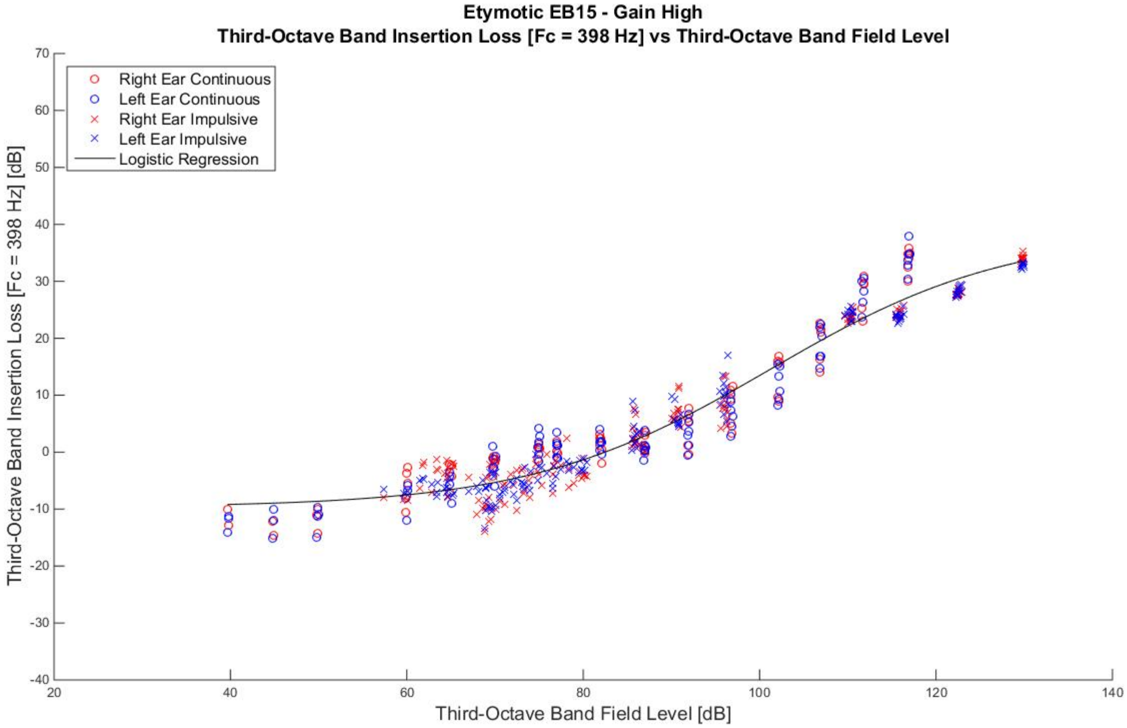

Figure A-200. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

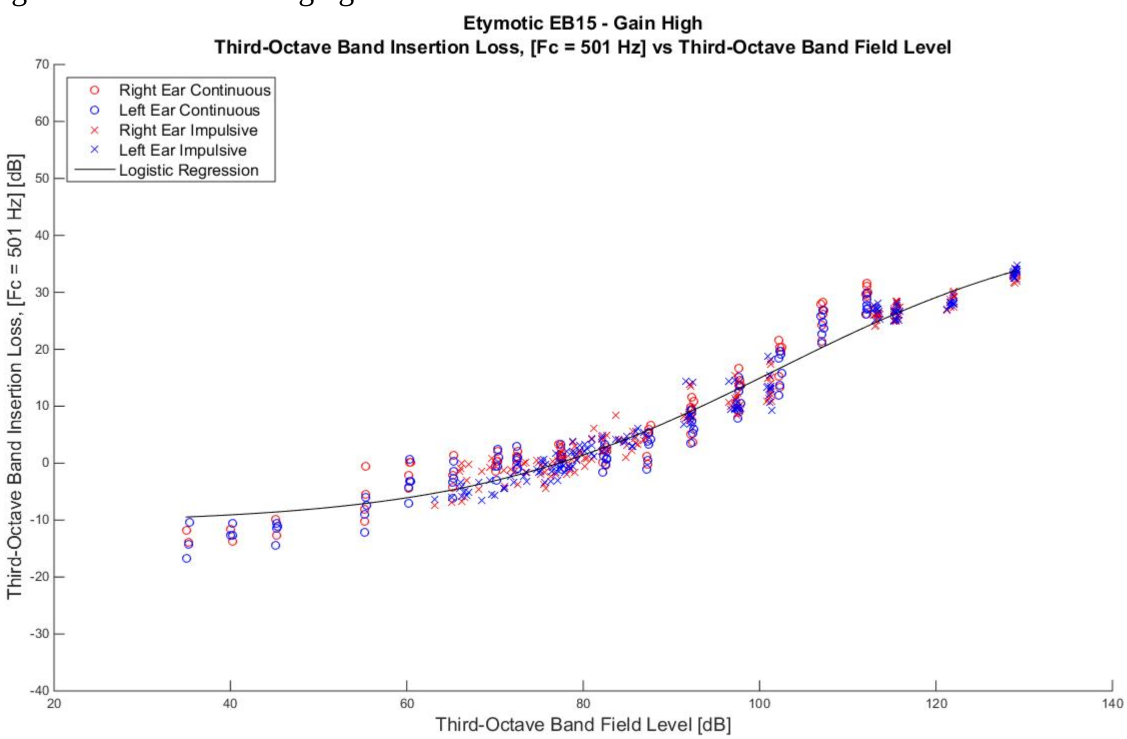

Figure A-201. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

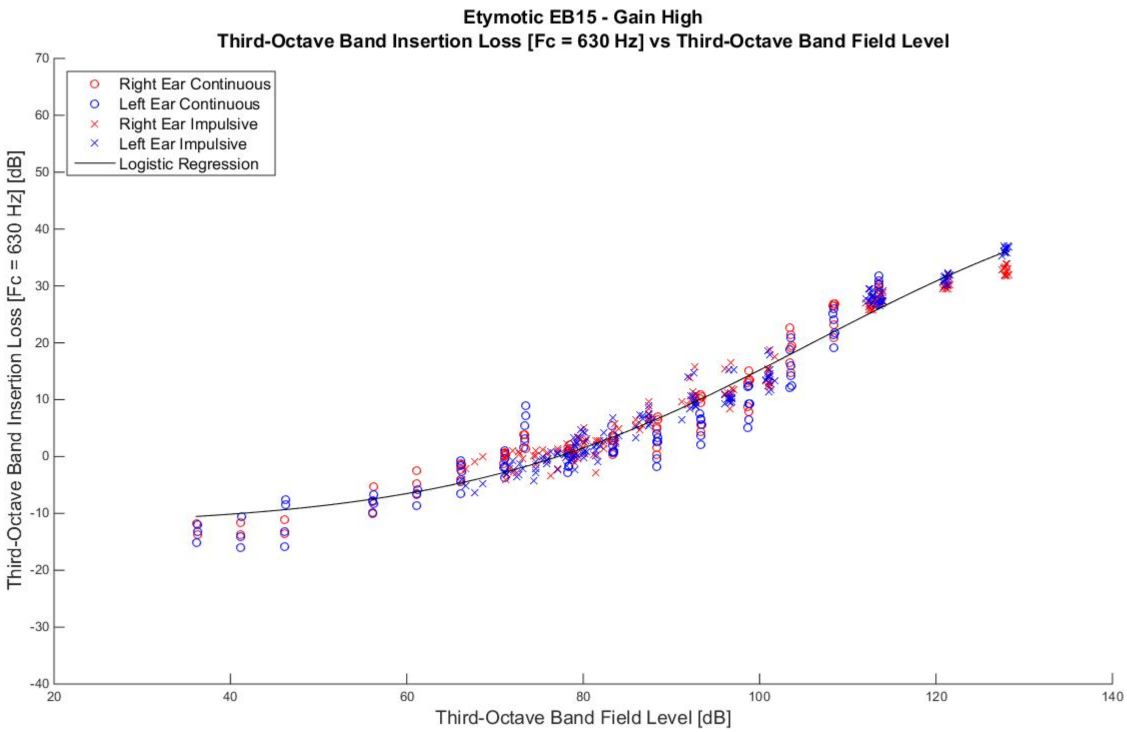

Figure A-202. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

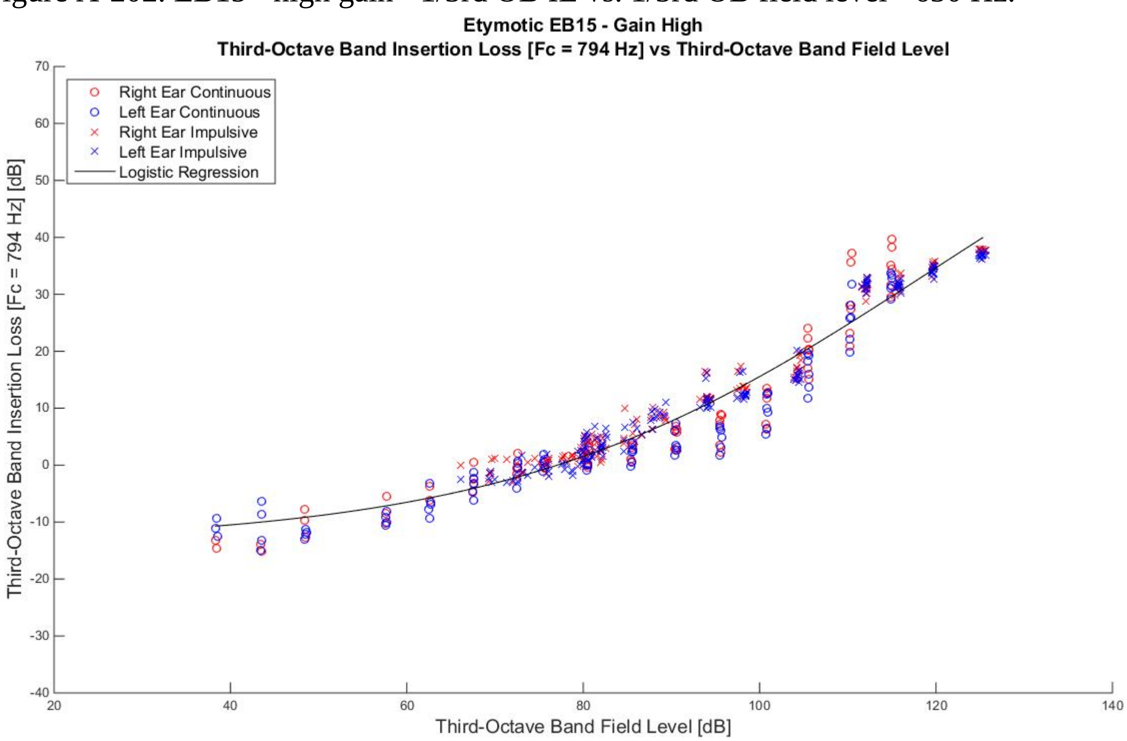

Figure A-203. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

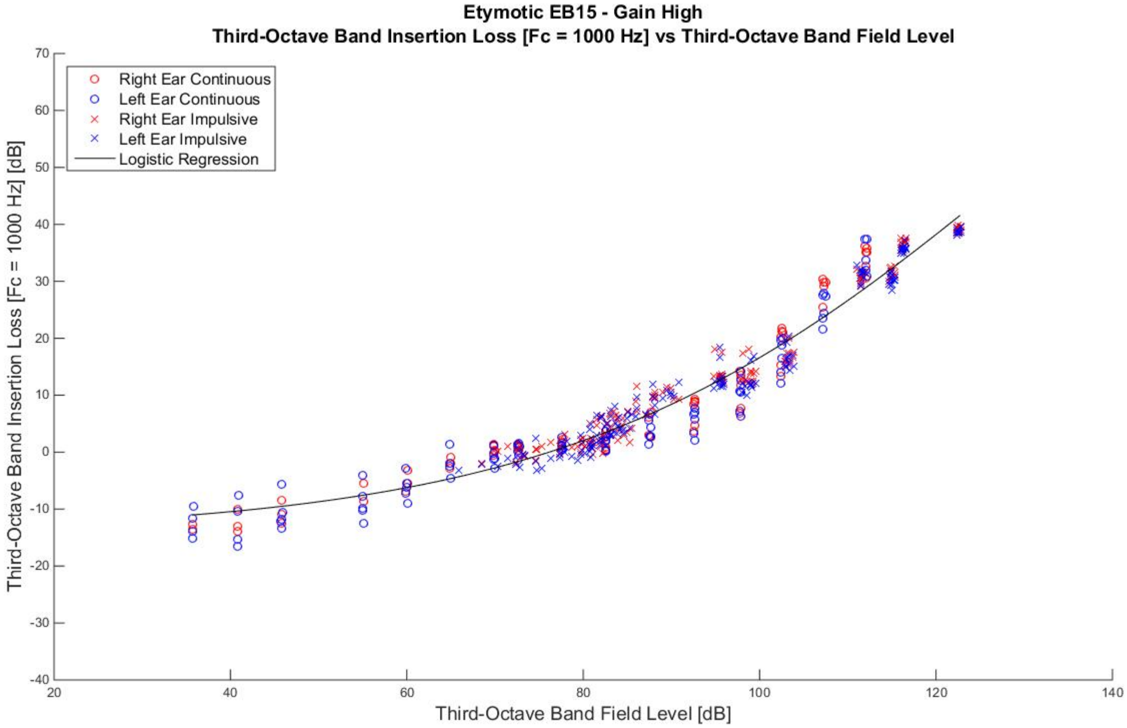

Figure A-204. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

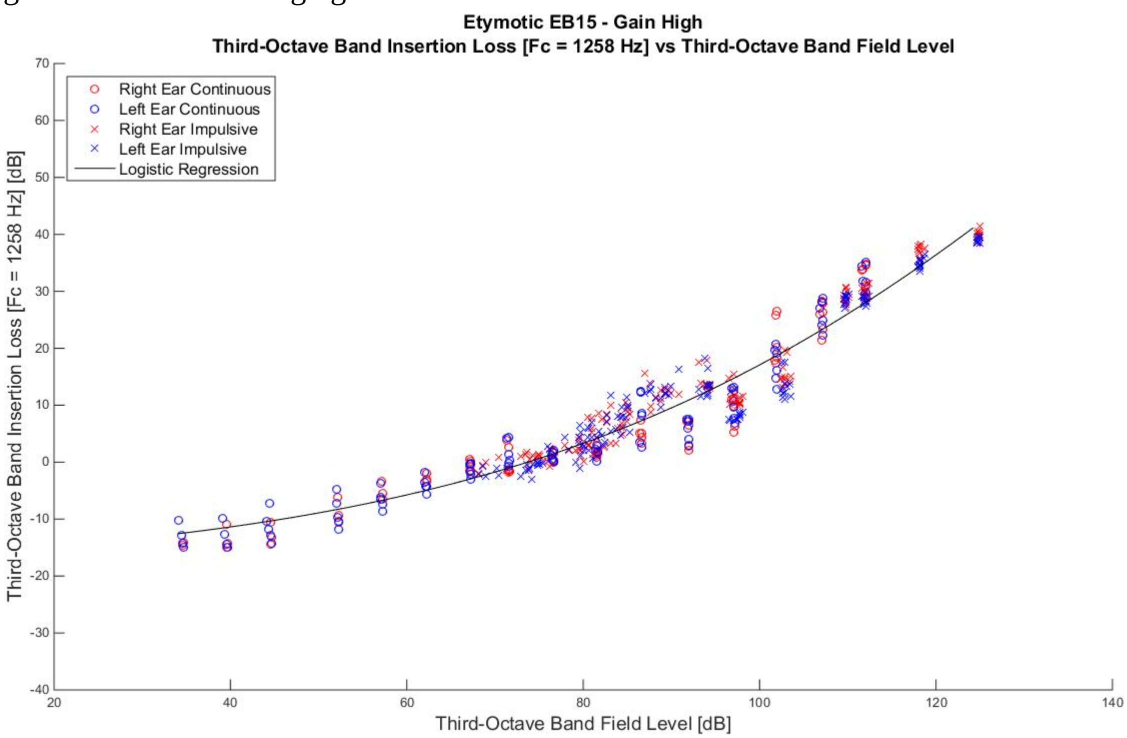

Figure A-205. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

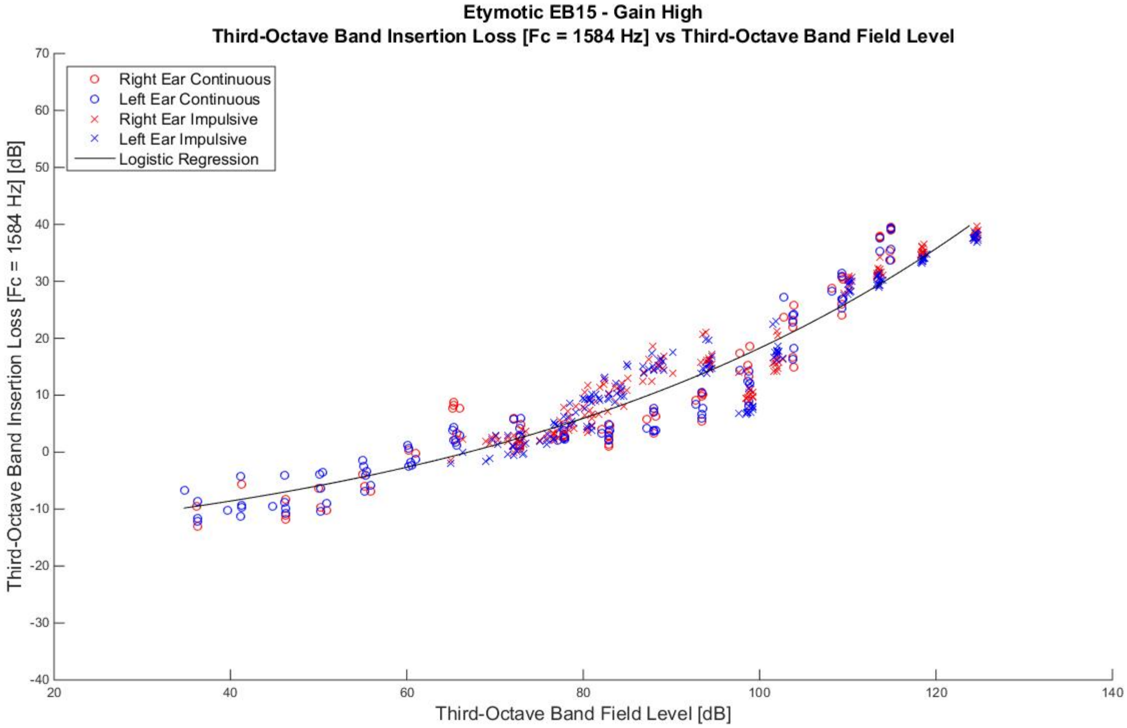

Figure A-206. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

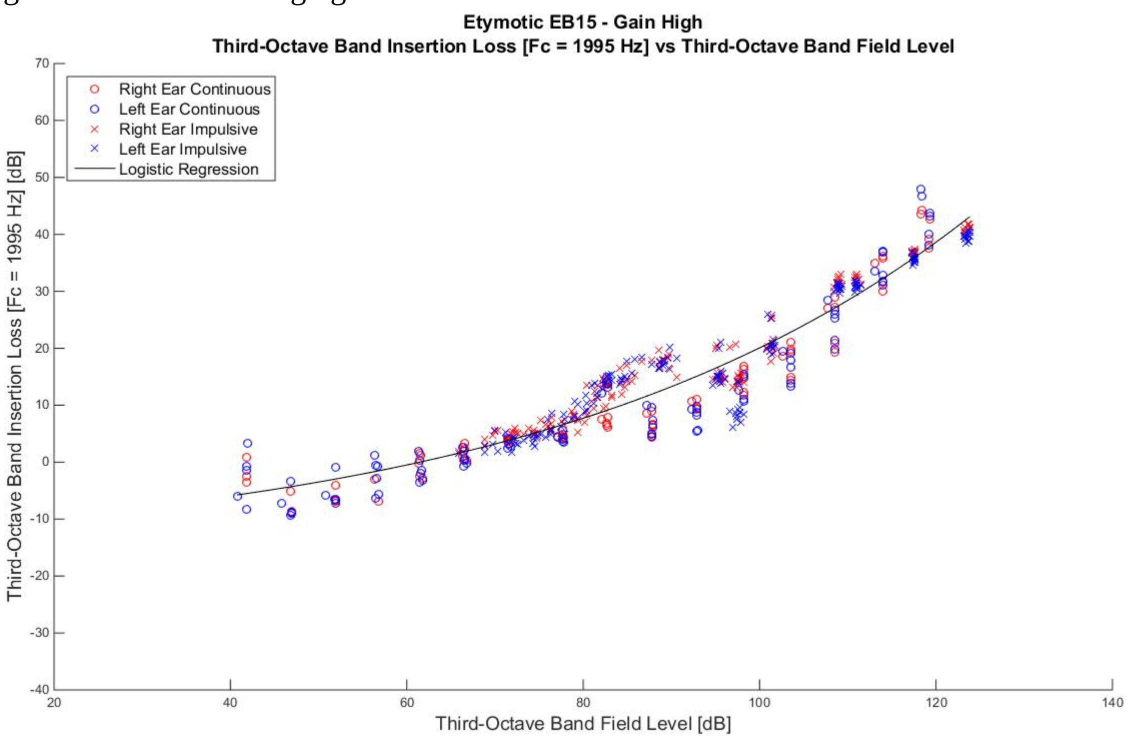

Figure A-207. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

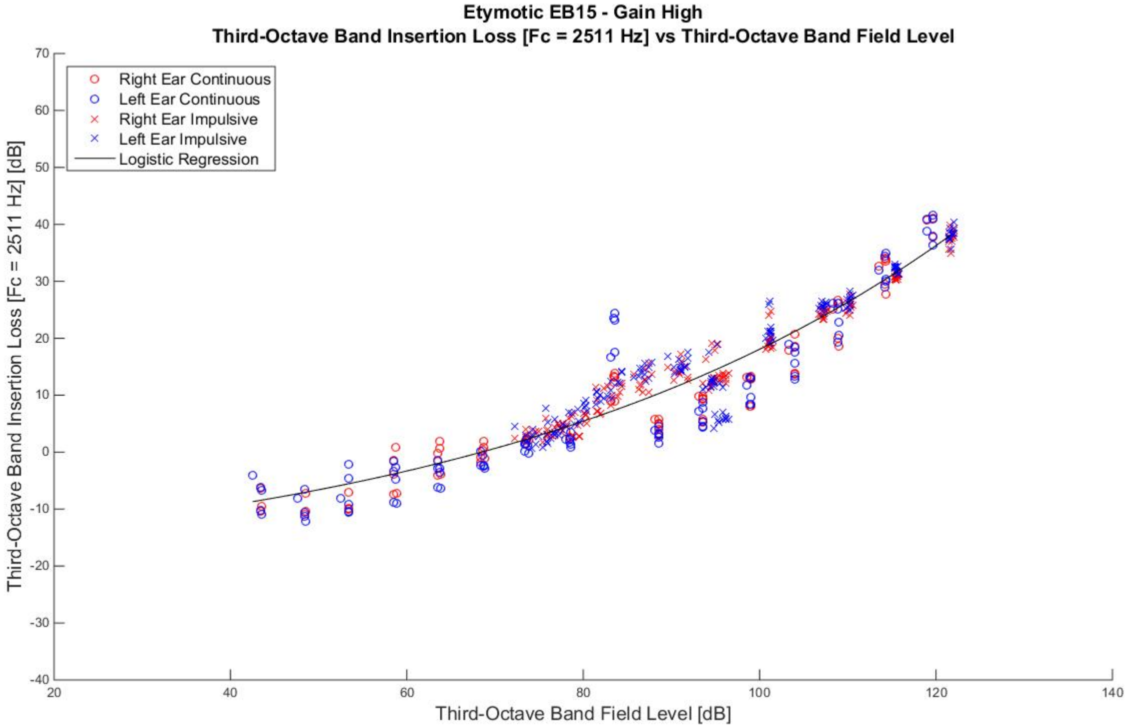

Figure A-208. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

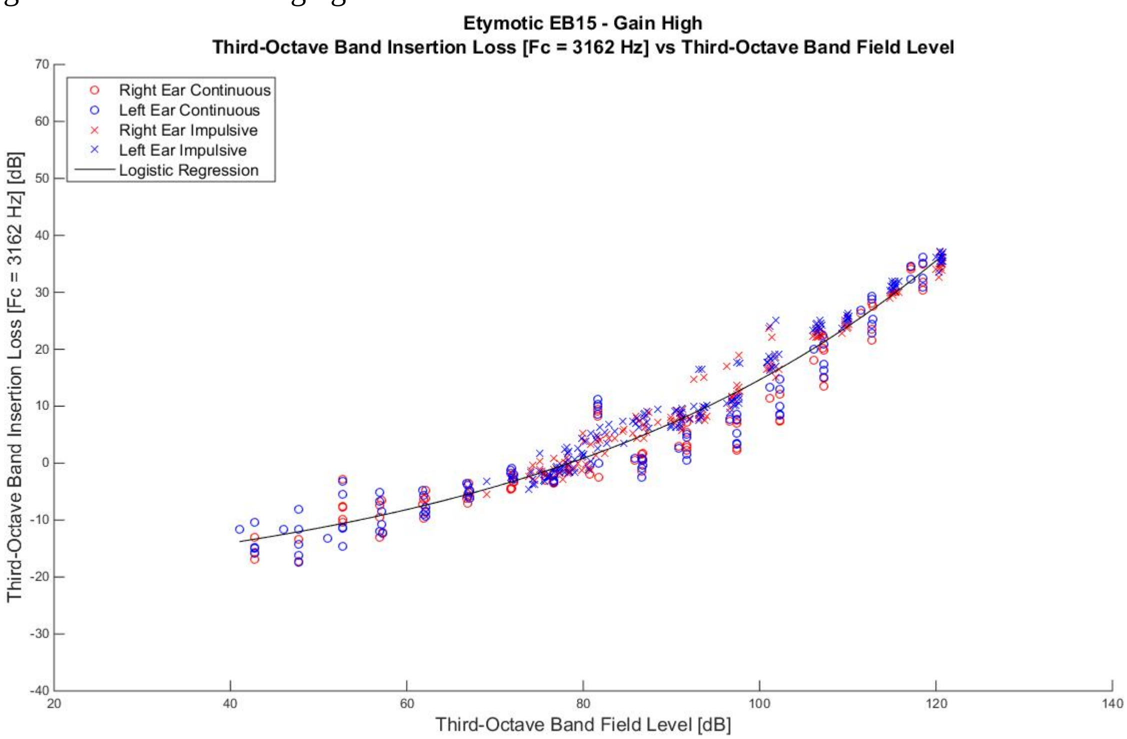

Figure A-209. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

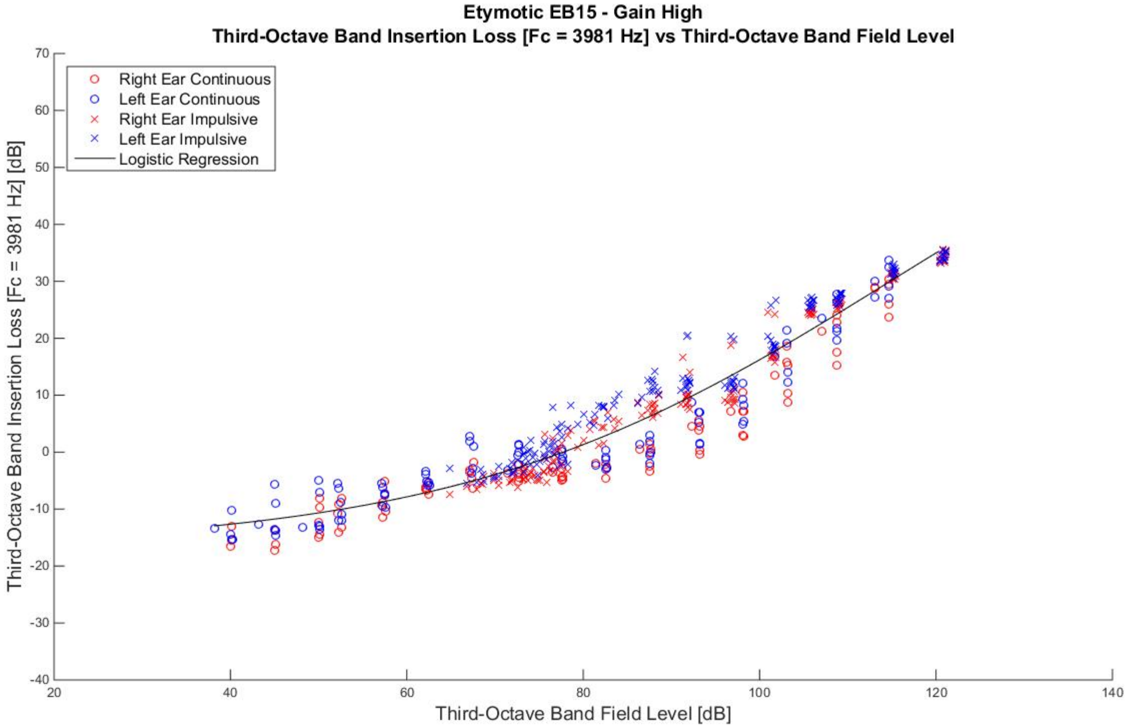

Figure A-210. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

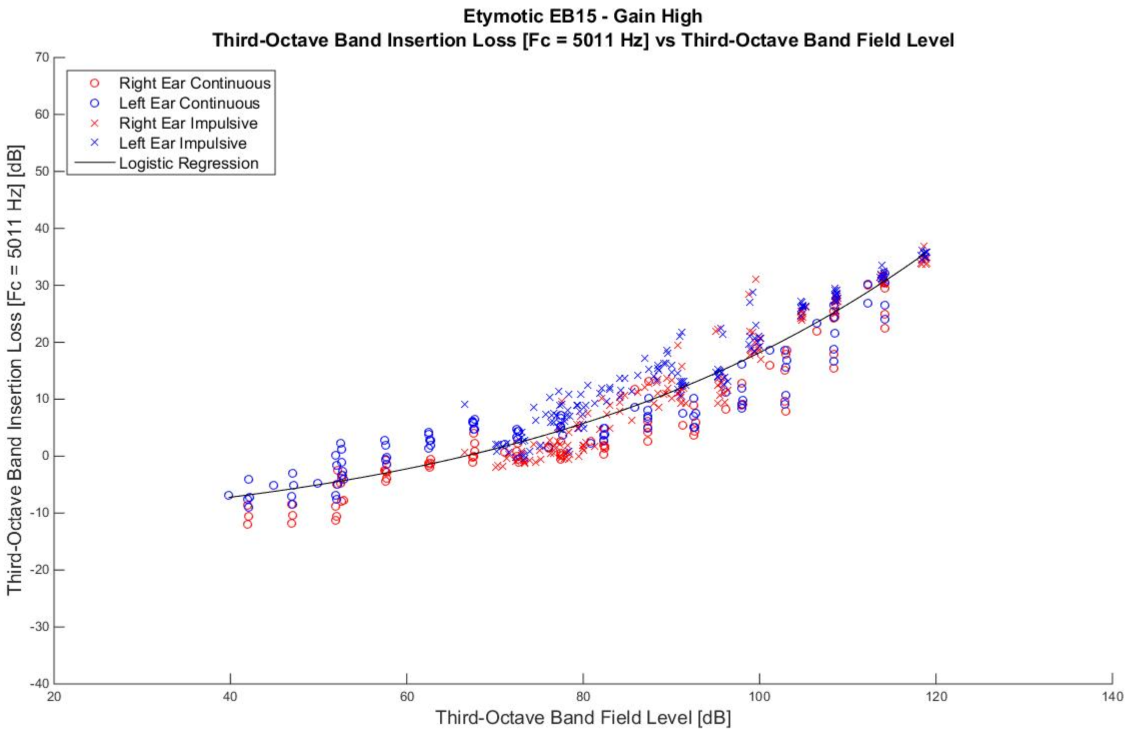

Figure A-211. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

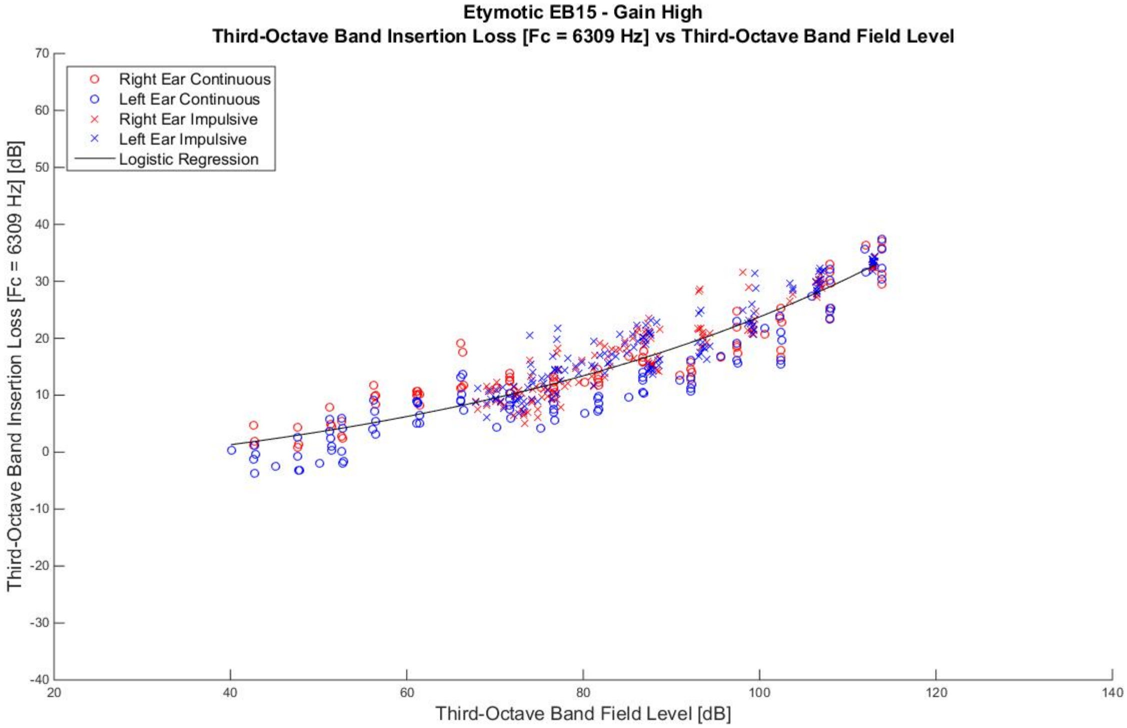

Figure A-212. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

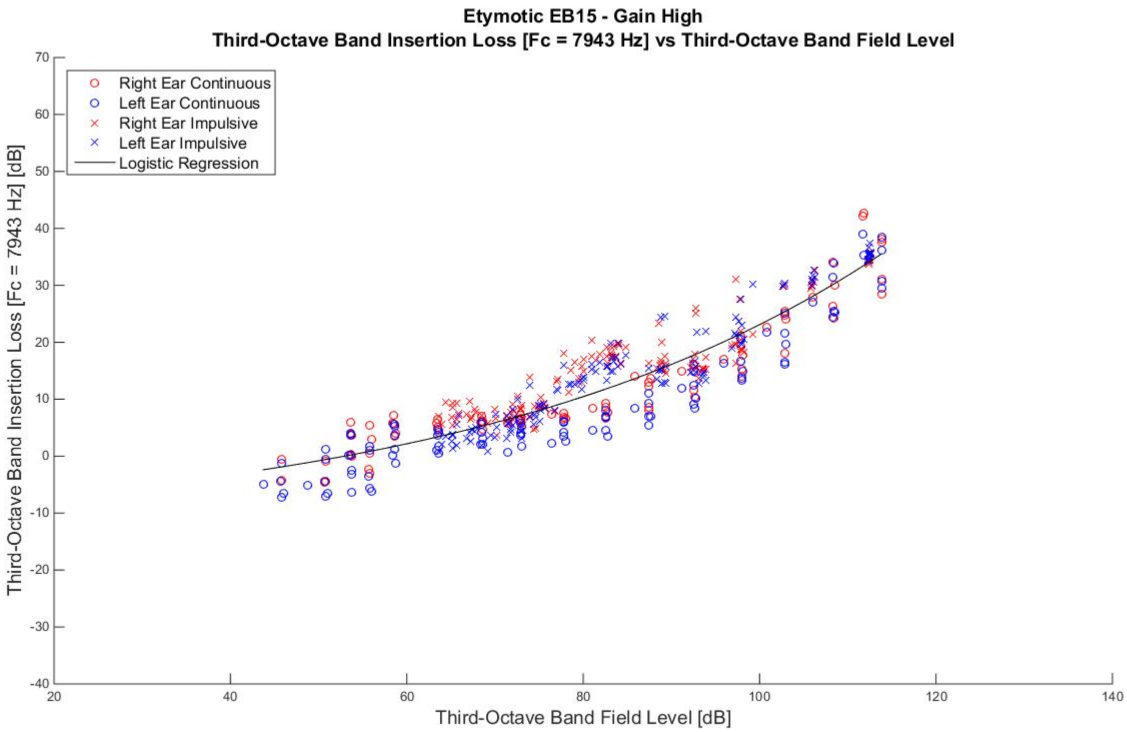

Figure A-213. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

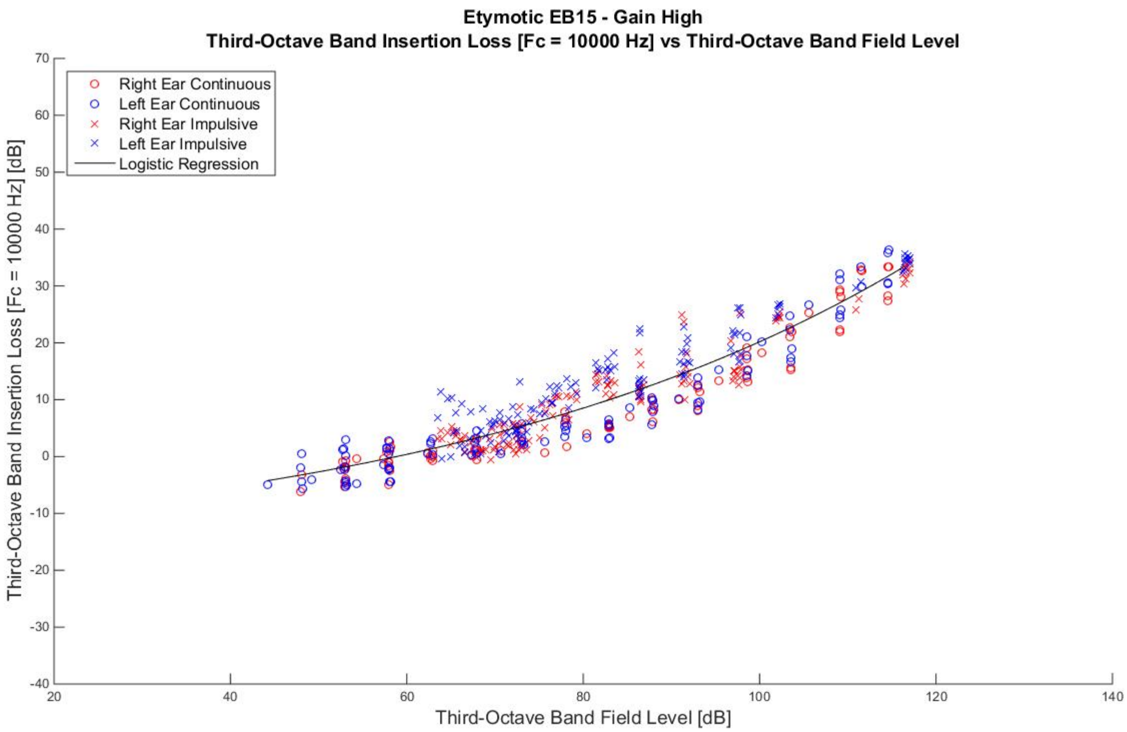

Figure A-214. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

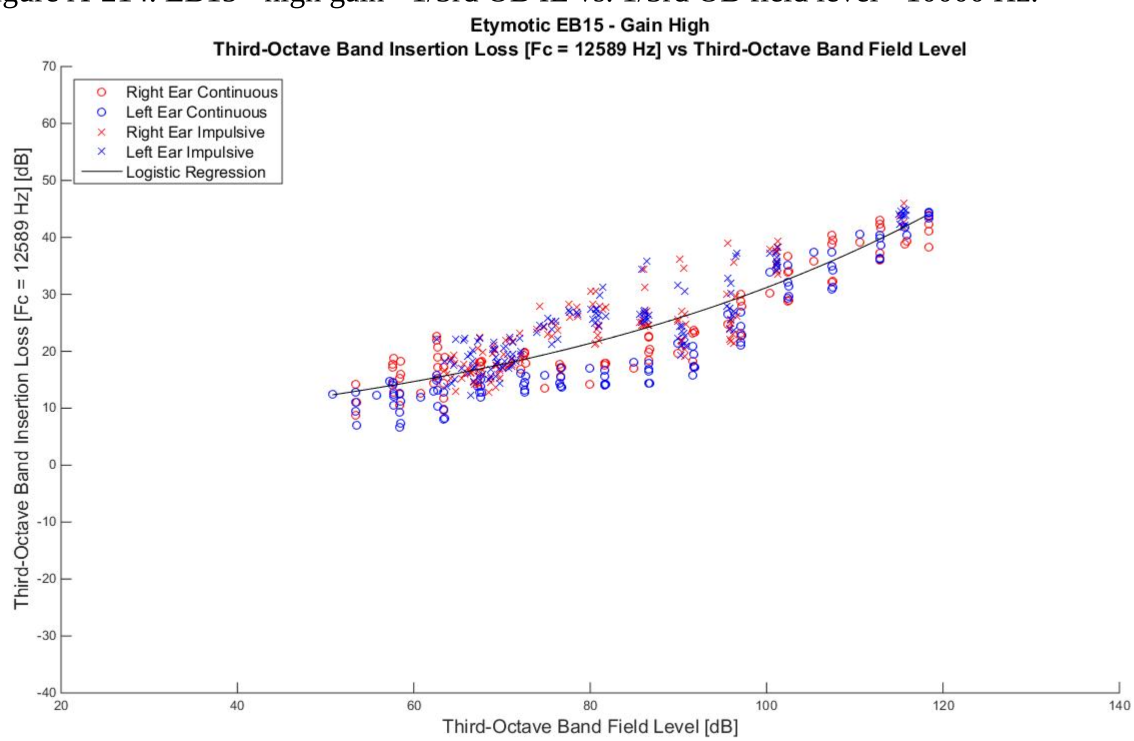

Figure A-215. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

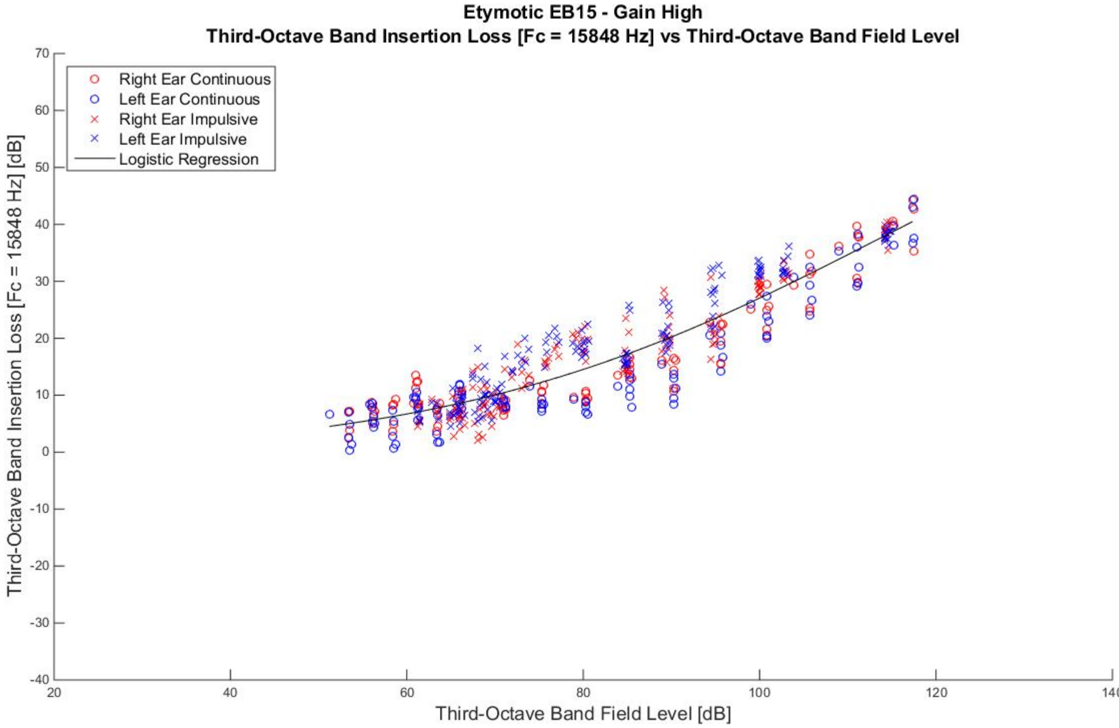

Figure A-216. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

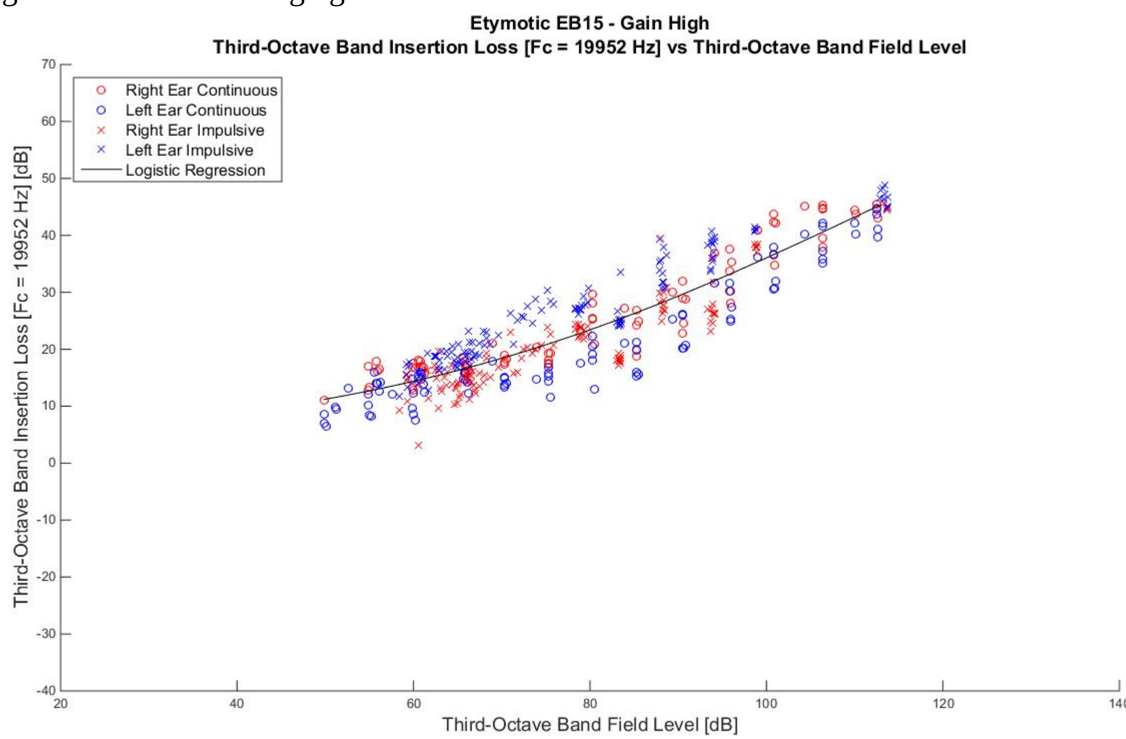

Figure A-217. EB15 - high gain - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

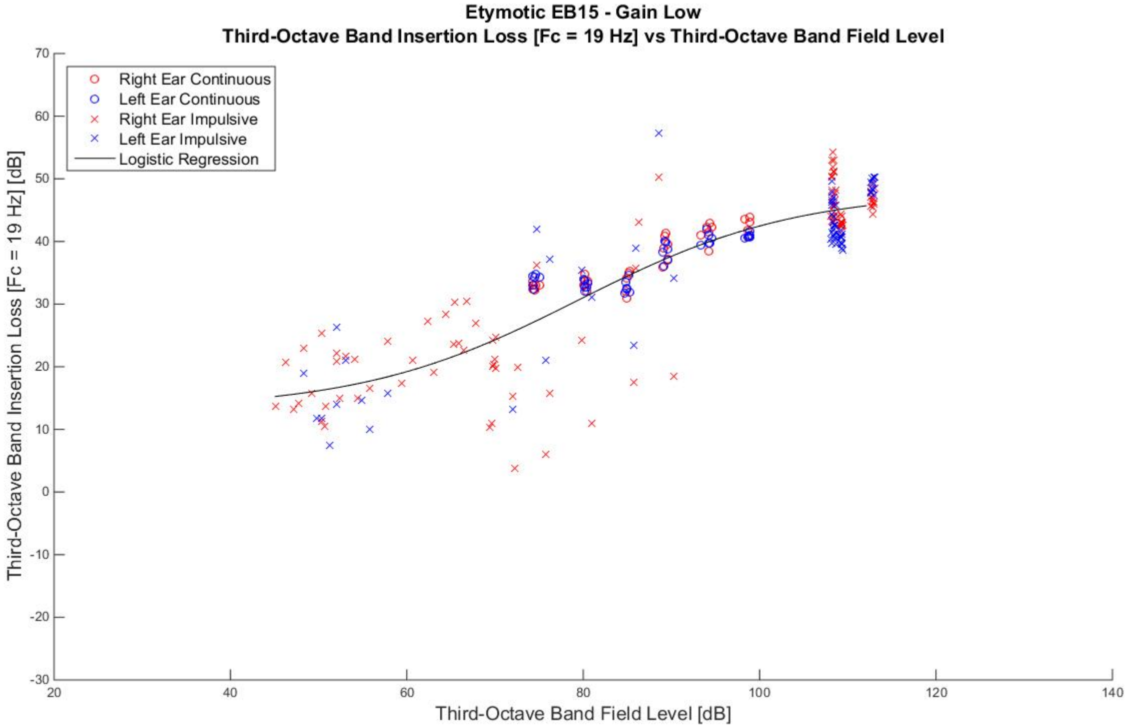

Figure A-218. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

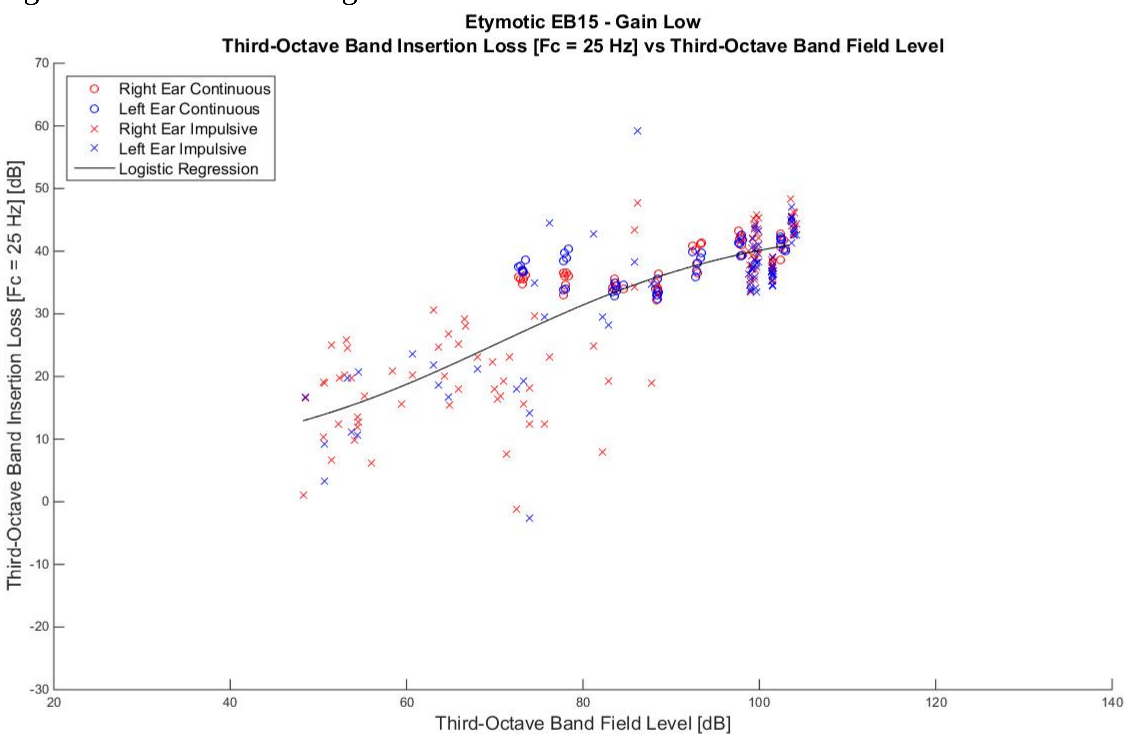

Figure A-219. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

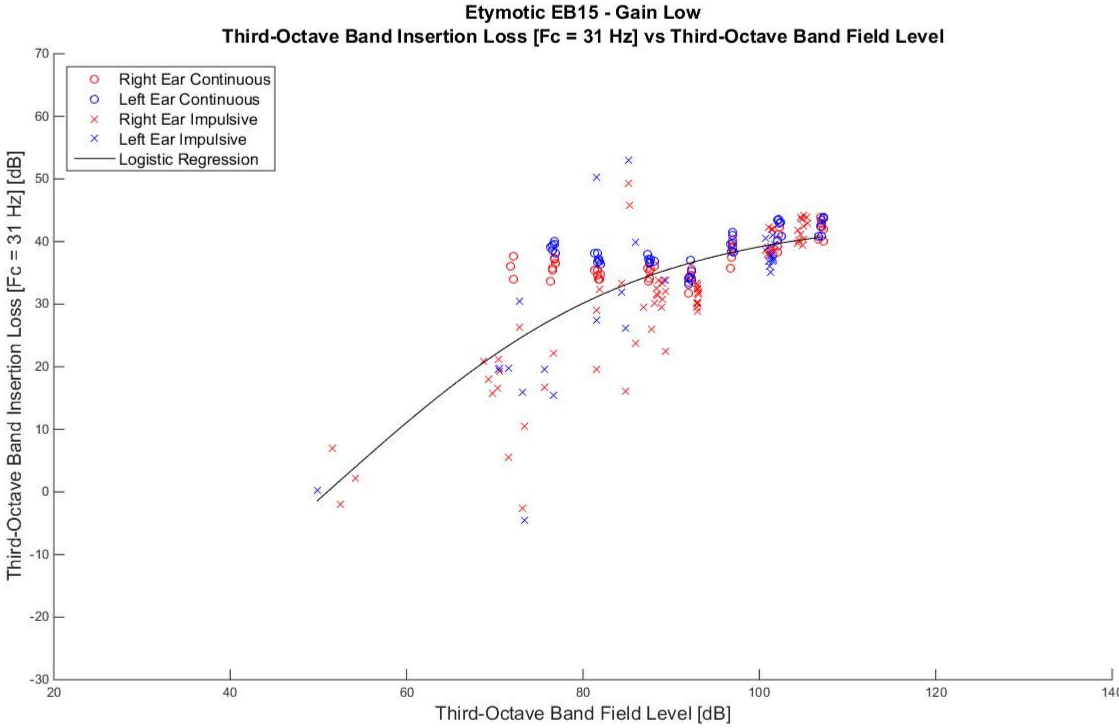

Figure A-220. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

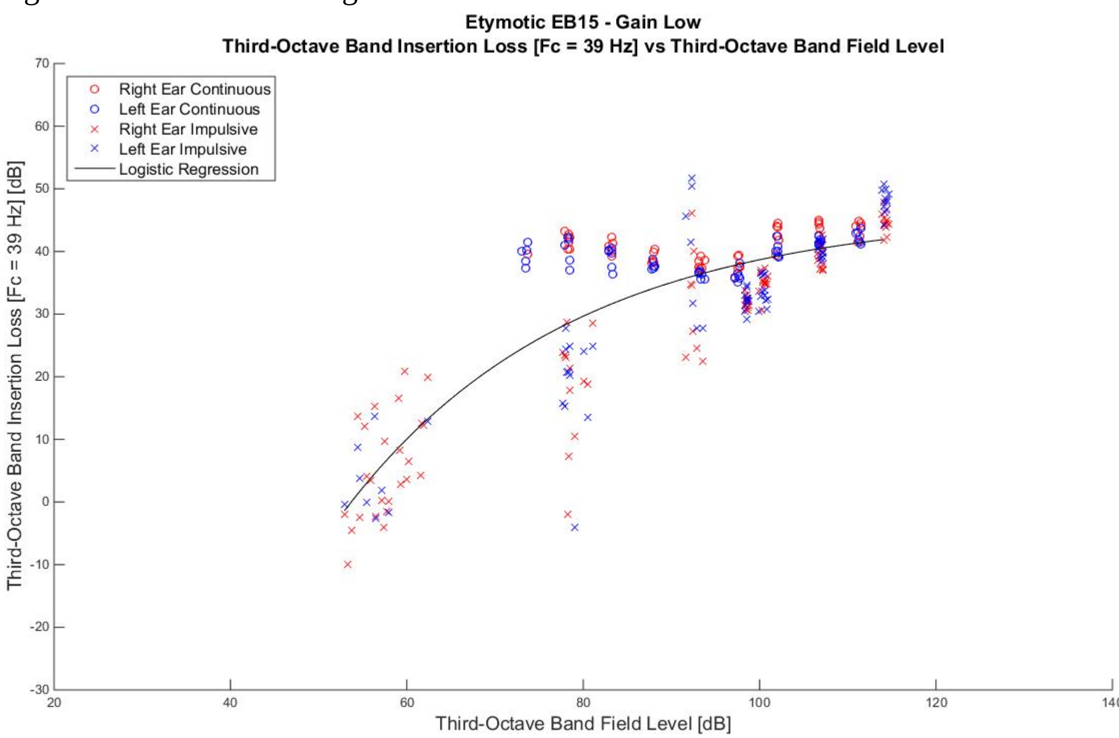

Figure A-221. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

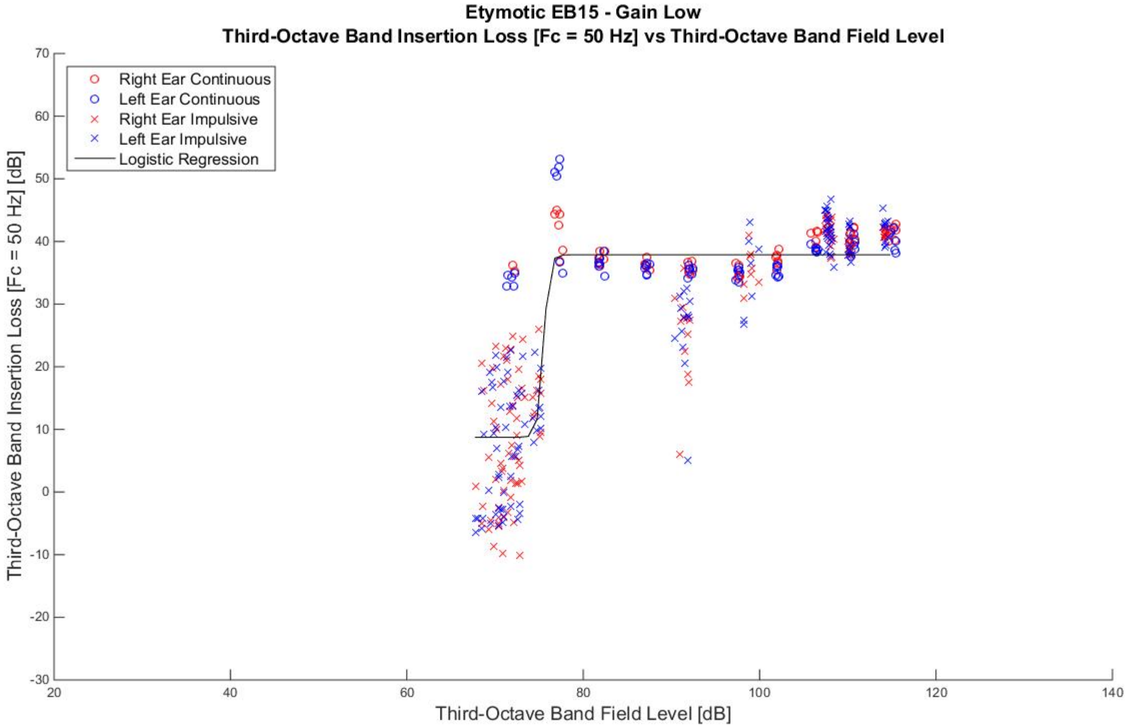

Figure A-222. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

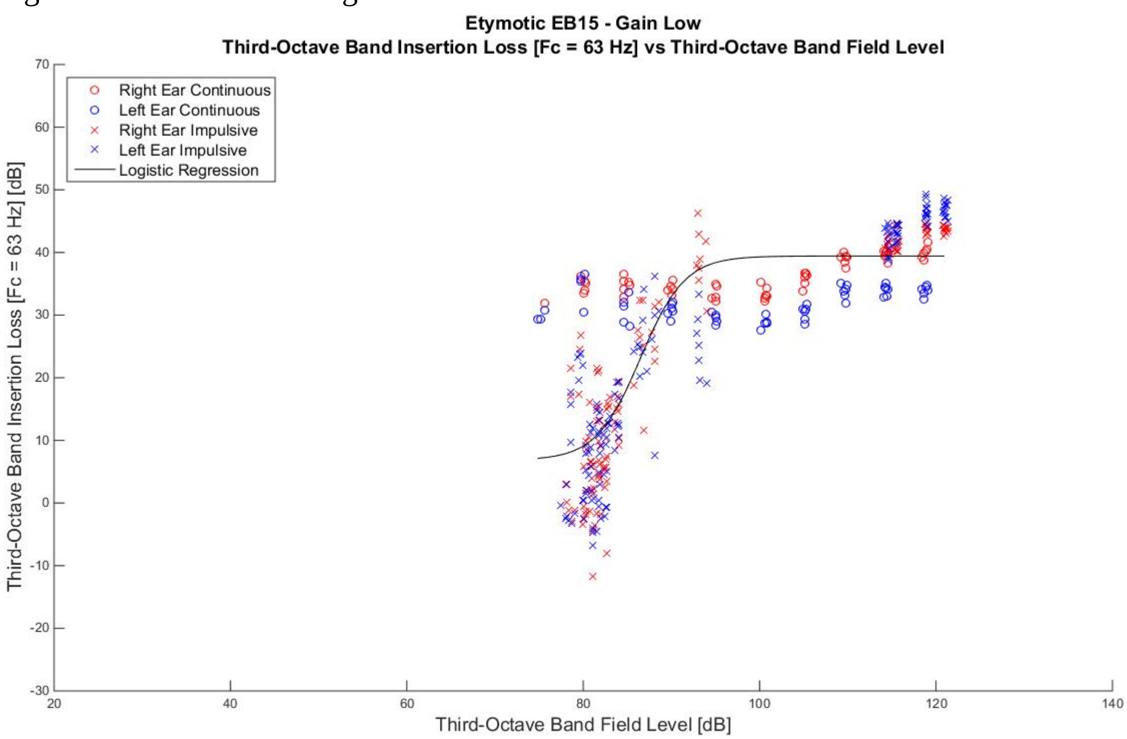

Figure A-223. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

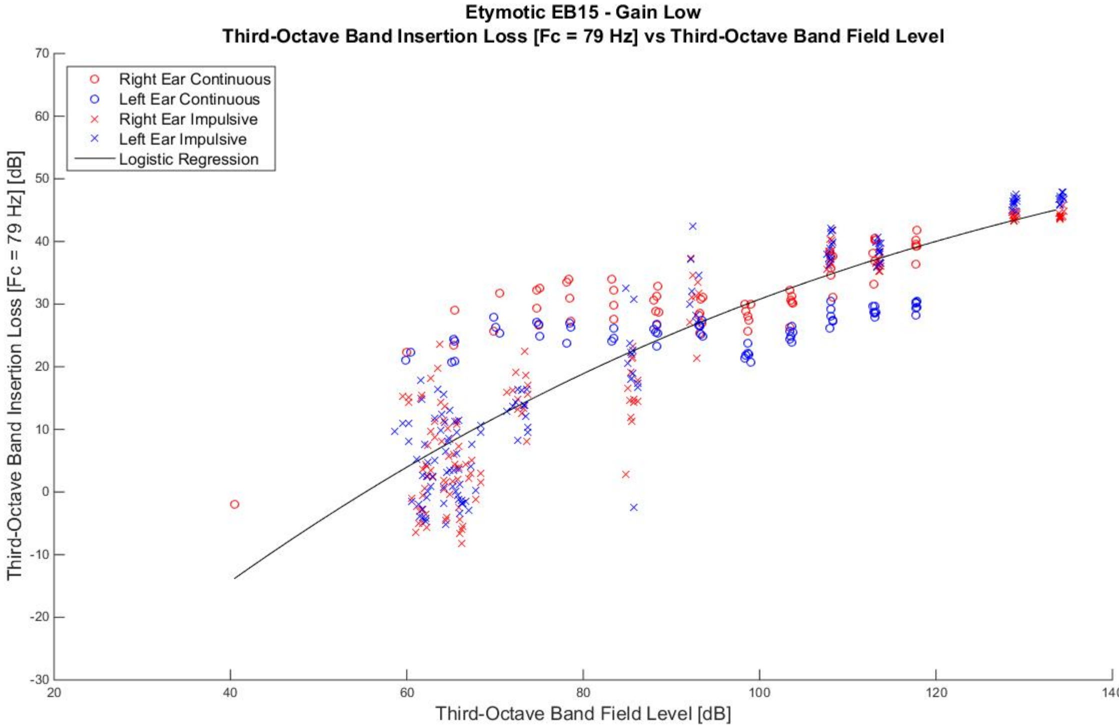

Figure A-224. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

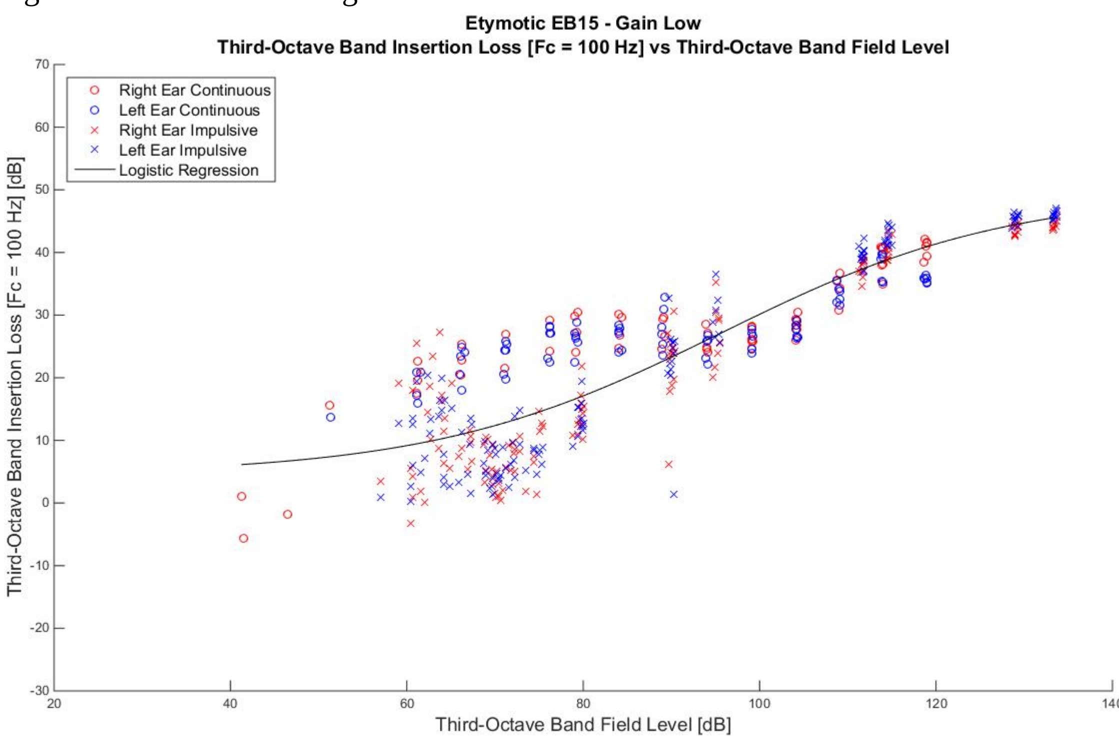

Figure A-225. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

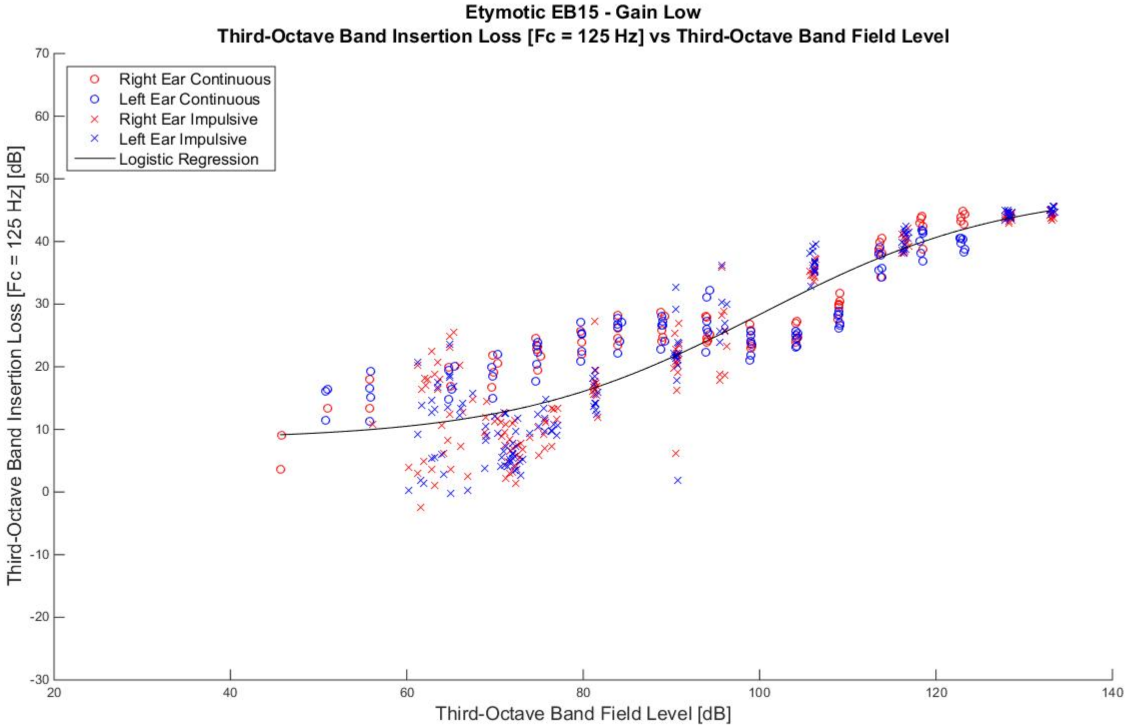

Figure A-226. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

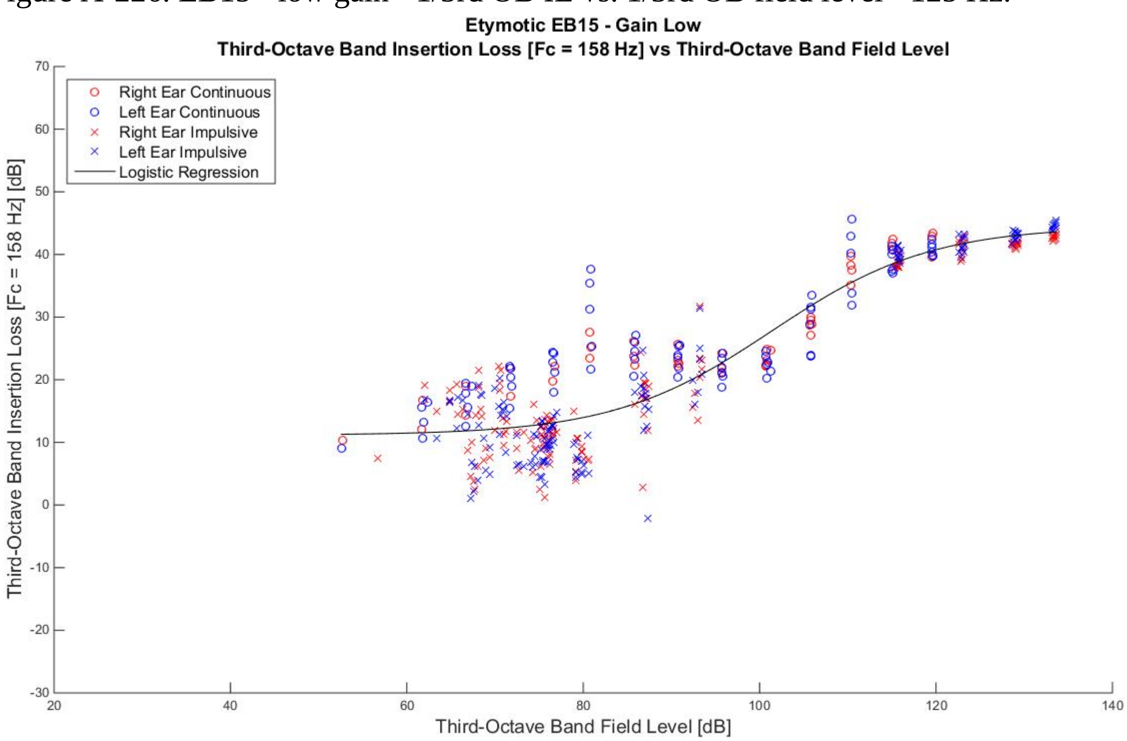

Figure A-227. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

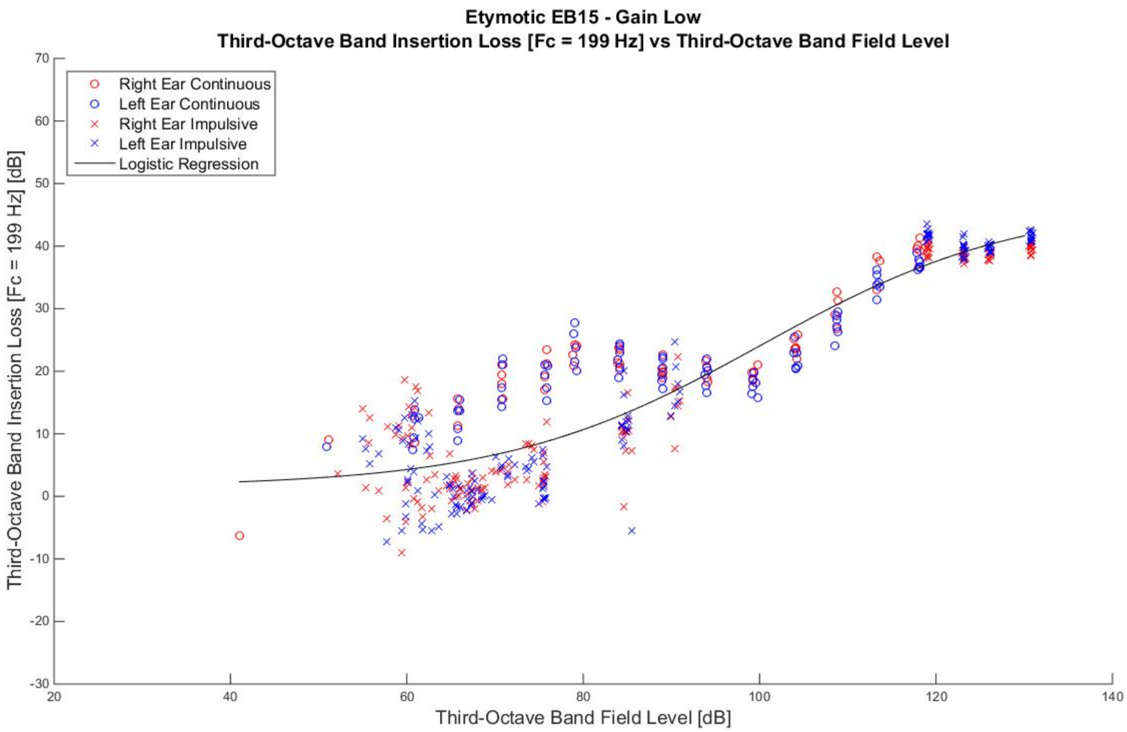

Figure A-228. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

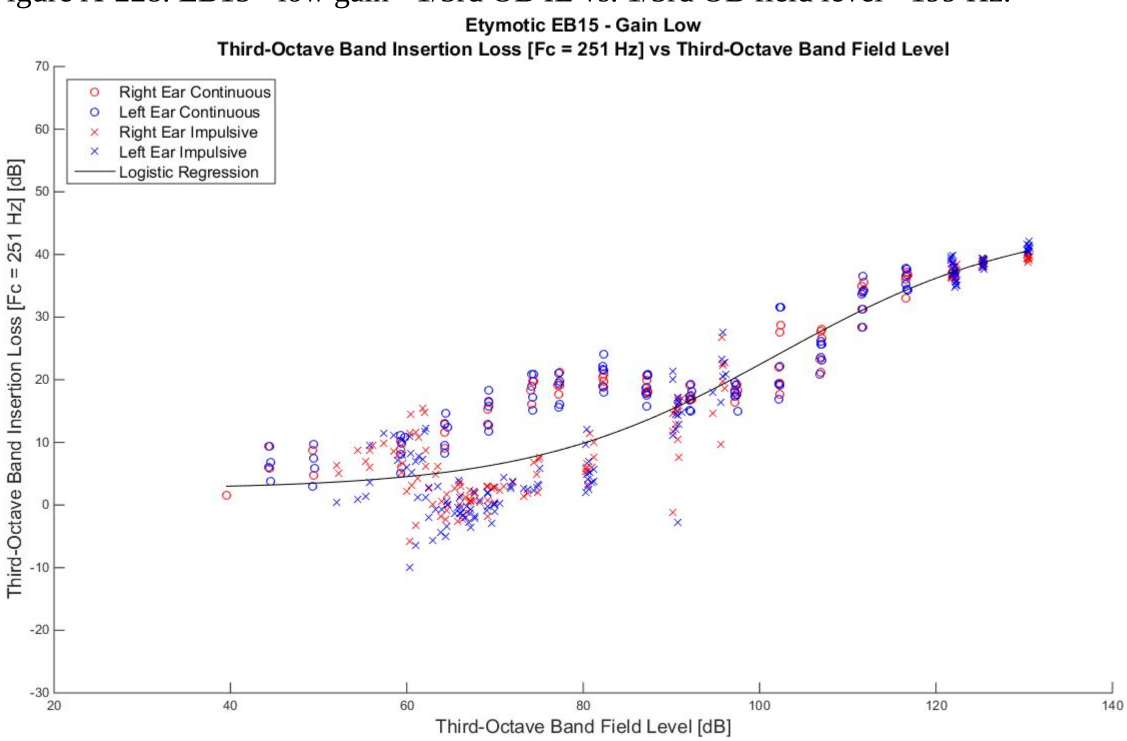

Figure A-229. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

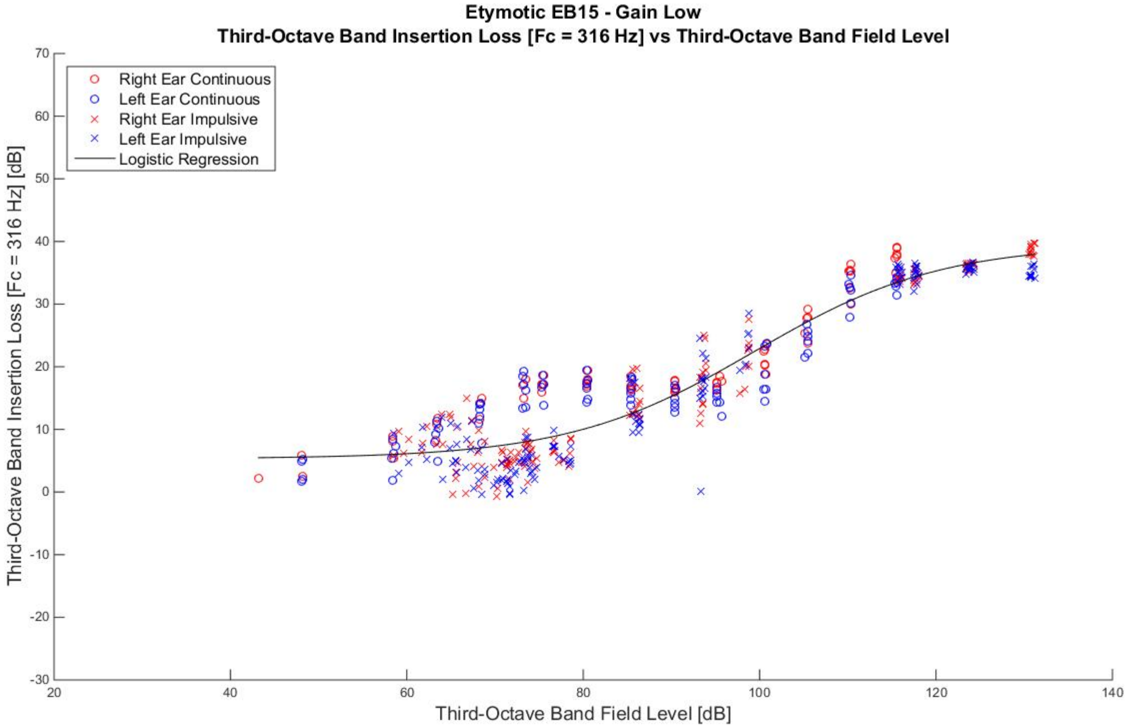

Figure A-230. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

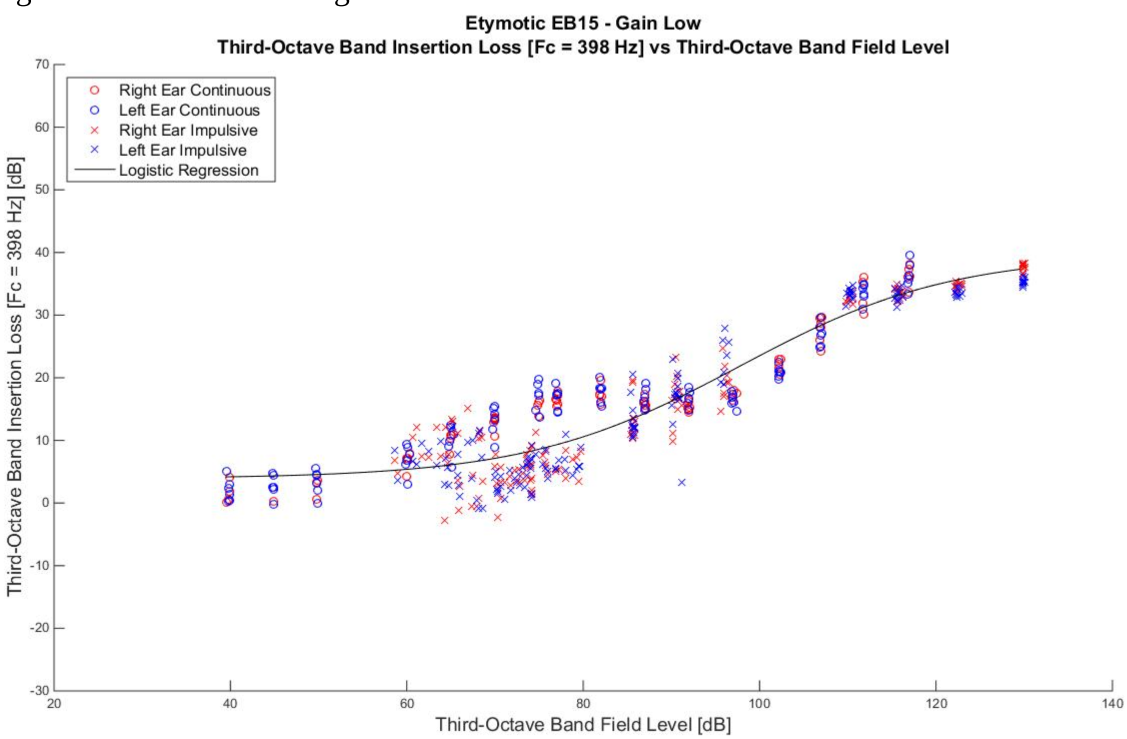

Figure A-231. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

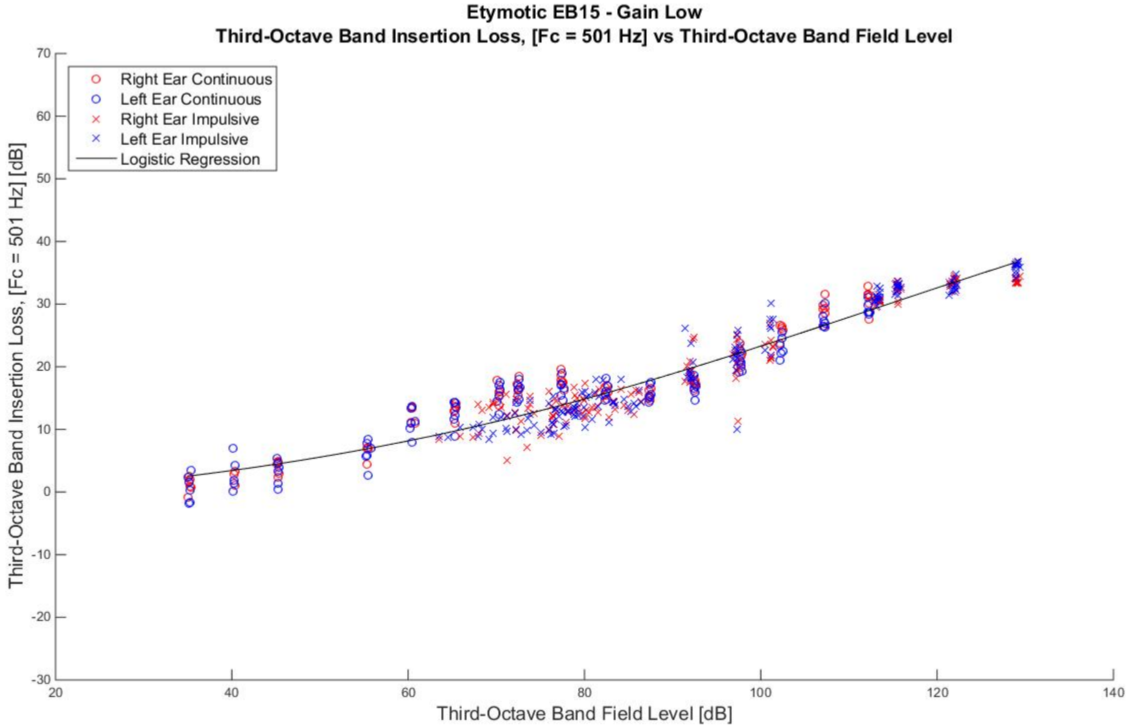

Figure A-232. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

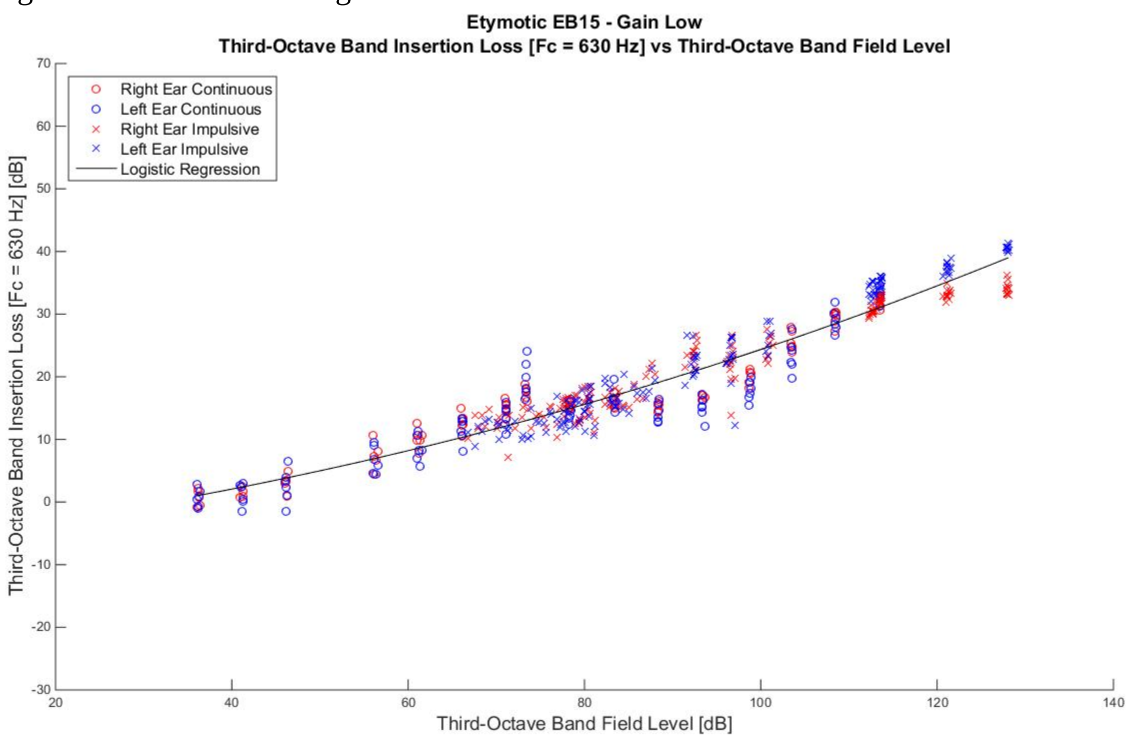

Figure A-233. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

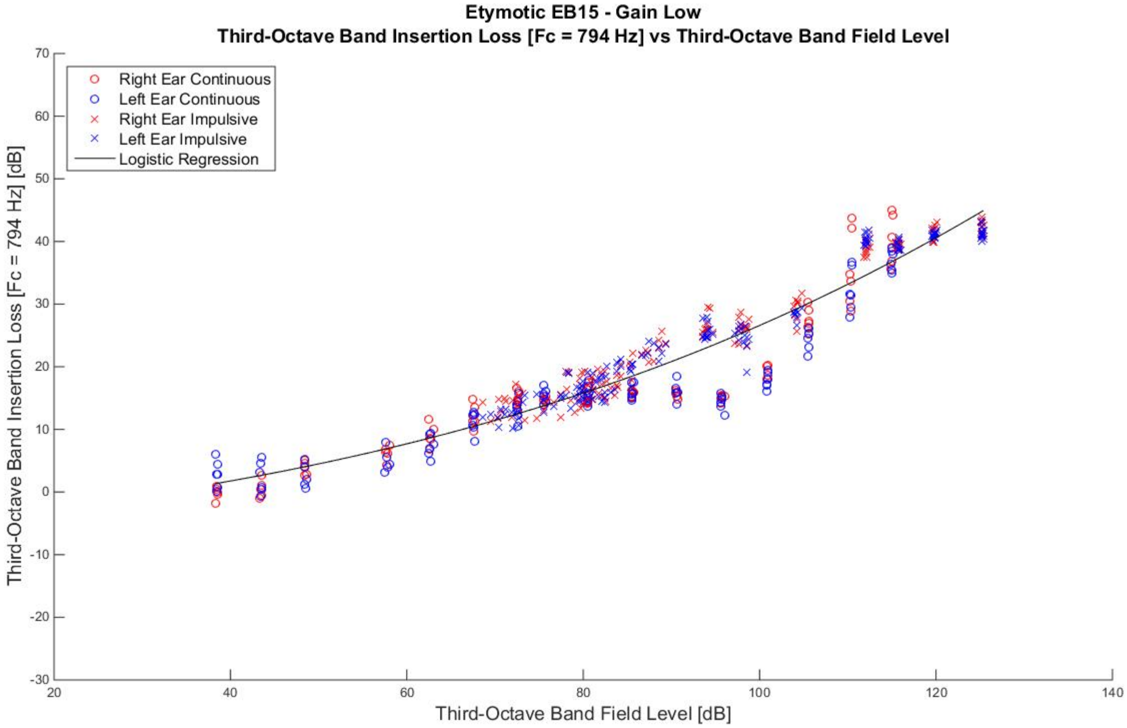

Figure A-234. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

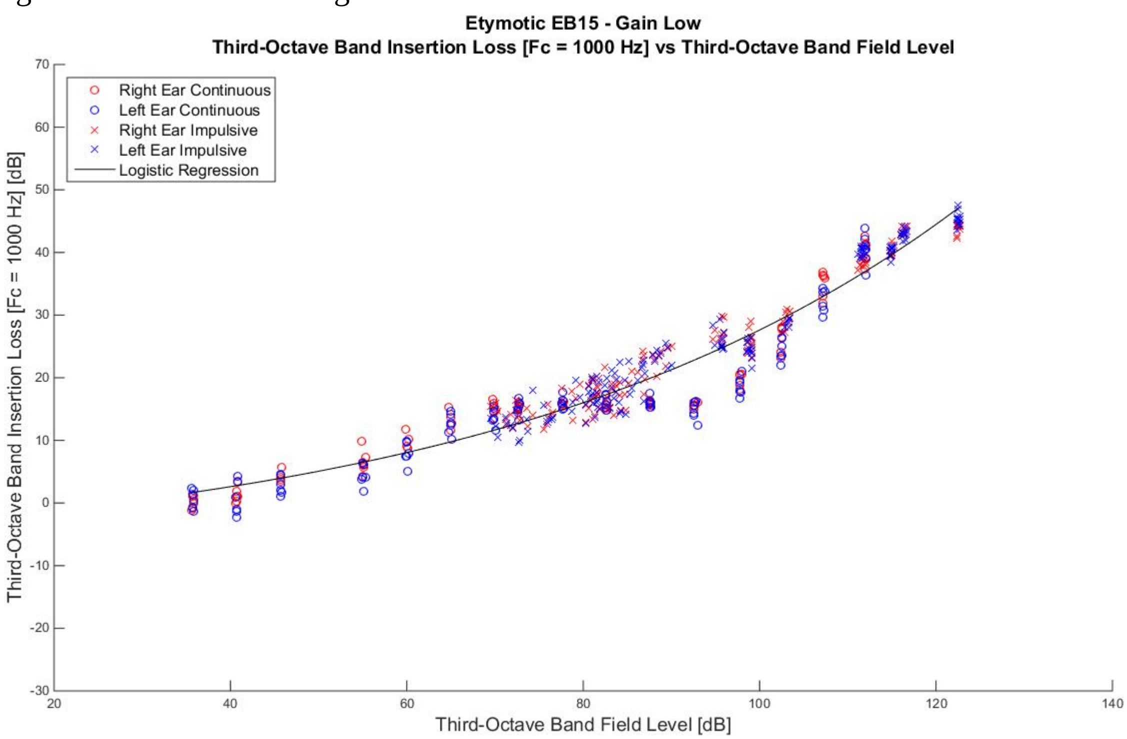

Figure A-235. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

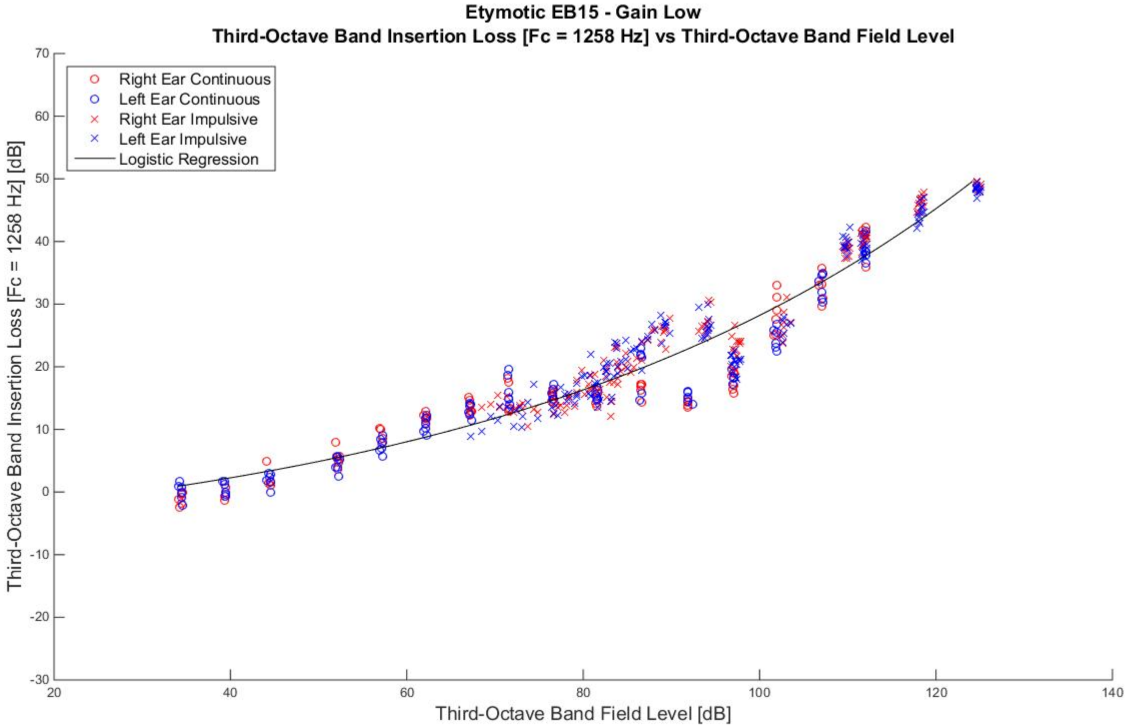

Figure A-236. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

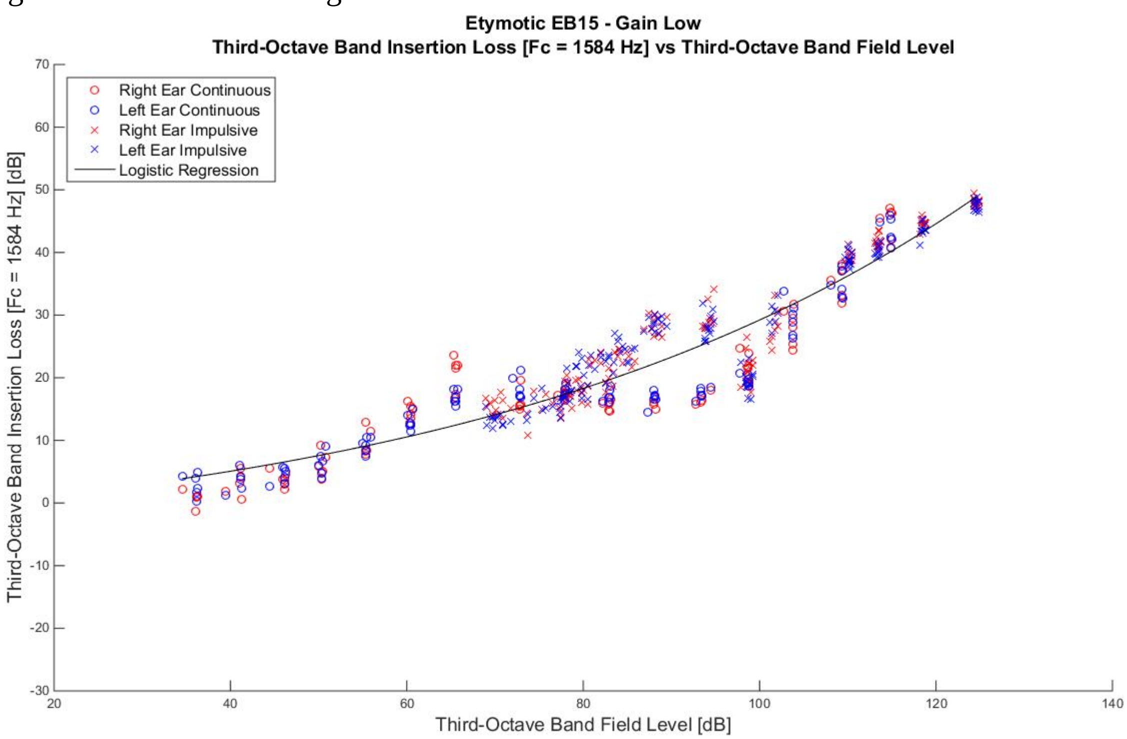

Figure A-237. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

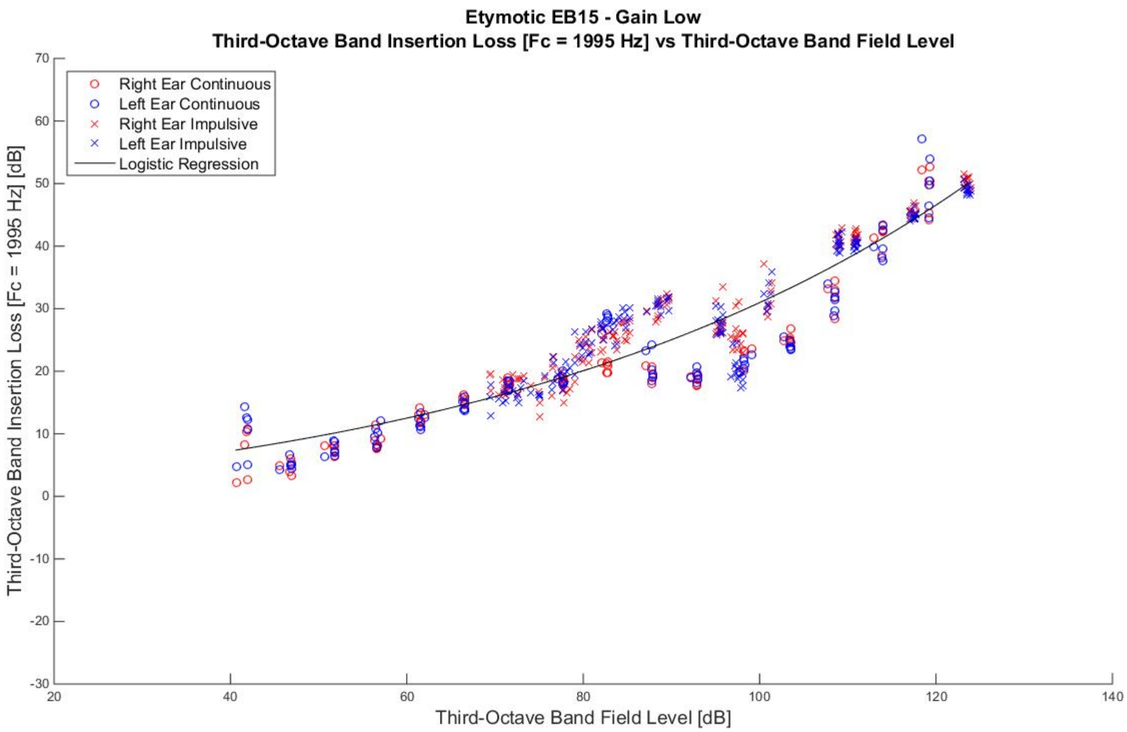

Figure A-238. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

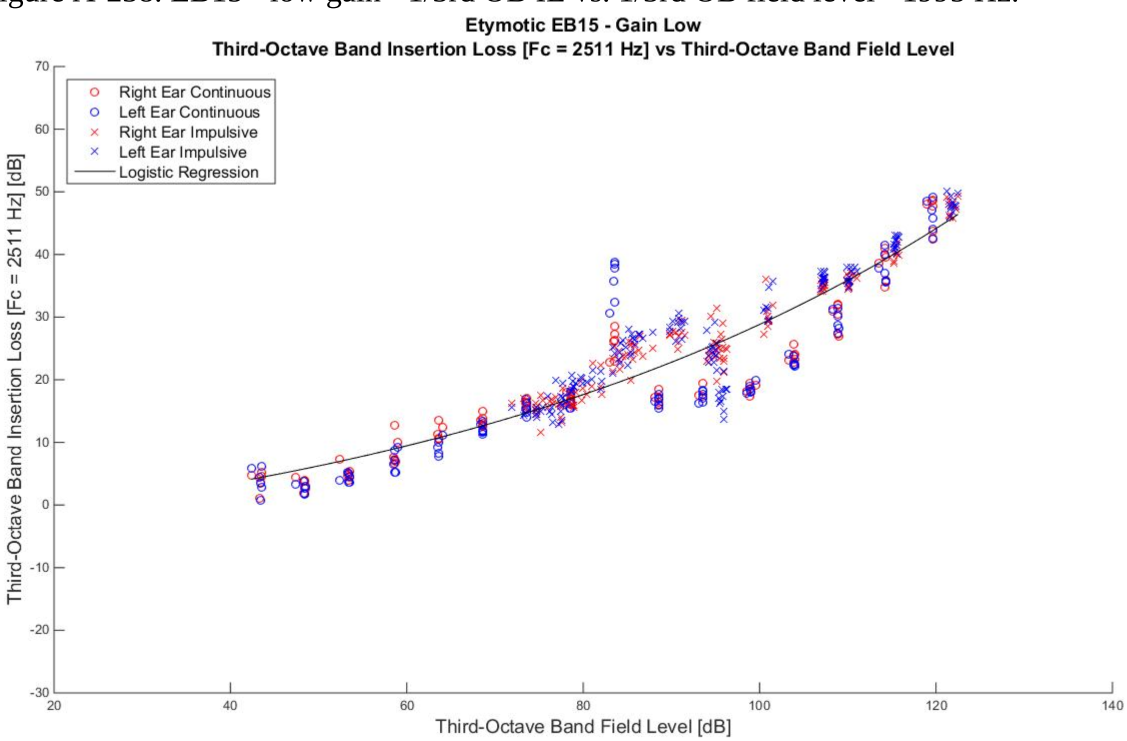

Figure A-239. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

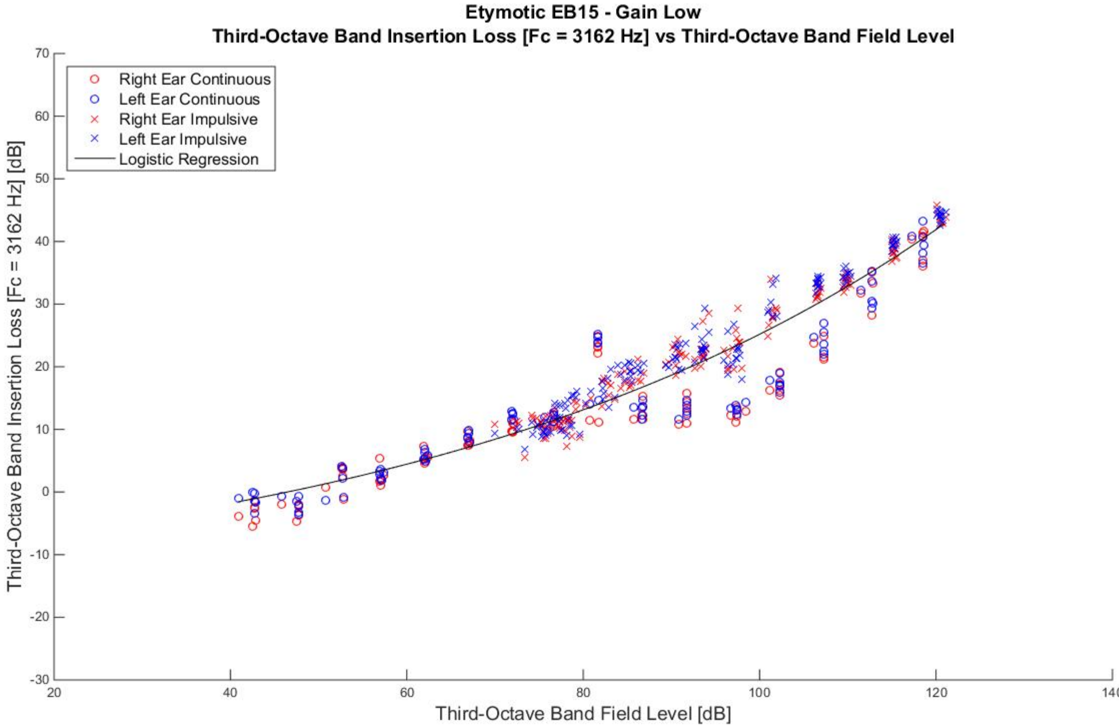

Figure A-240. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

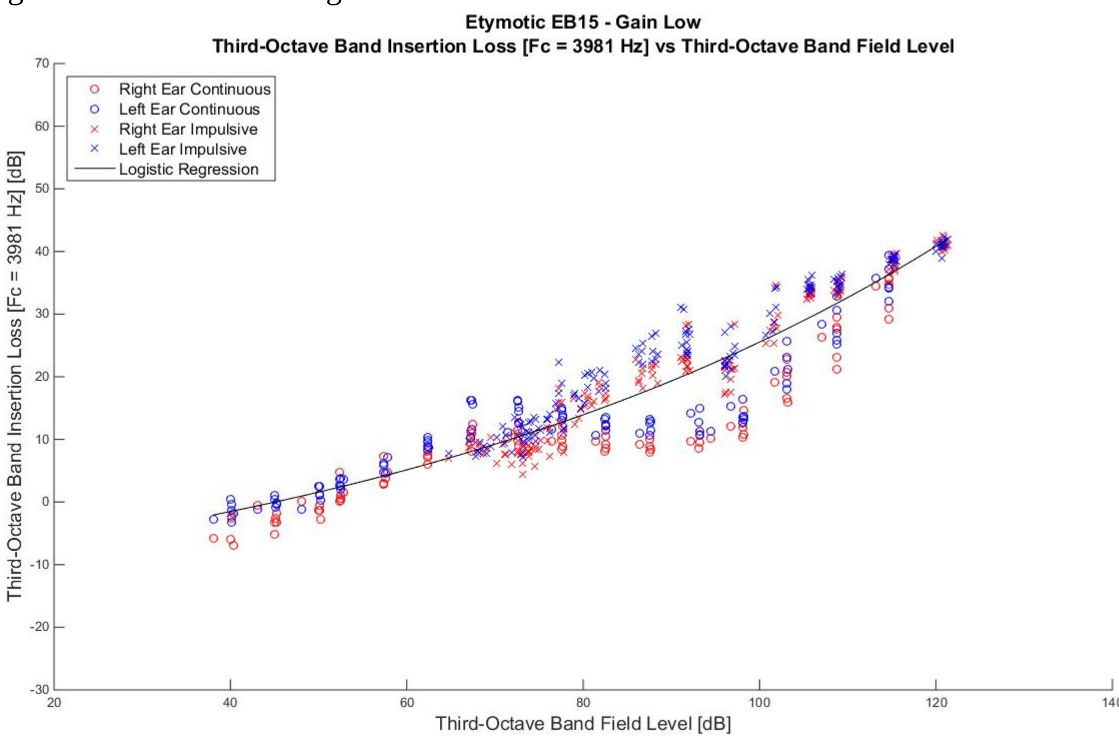

Figure A-241. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

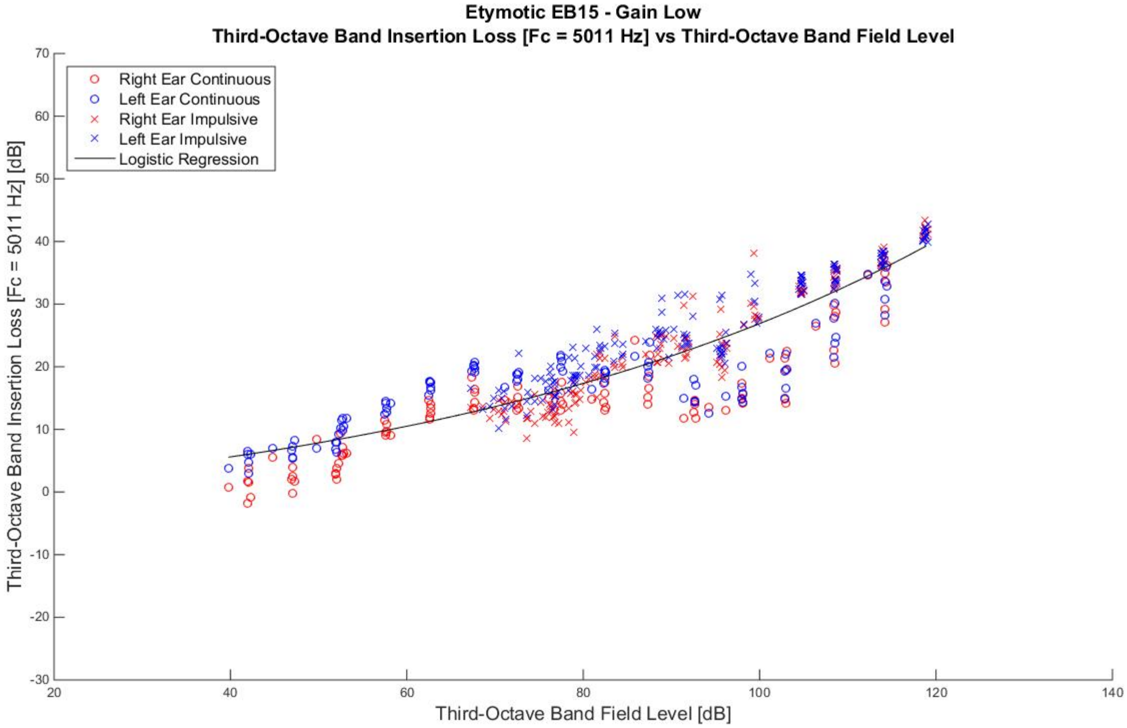

Figure A-242. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

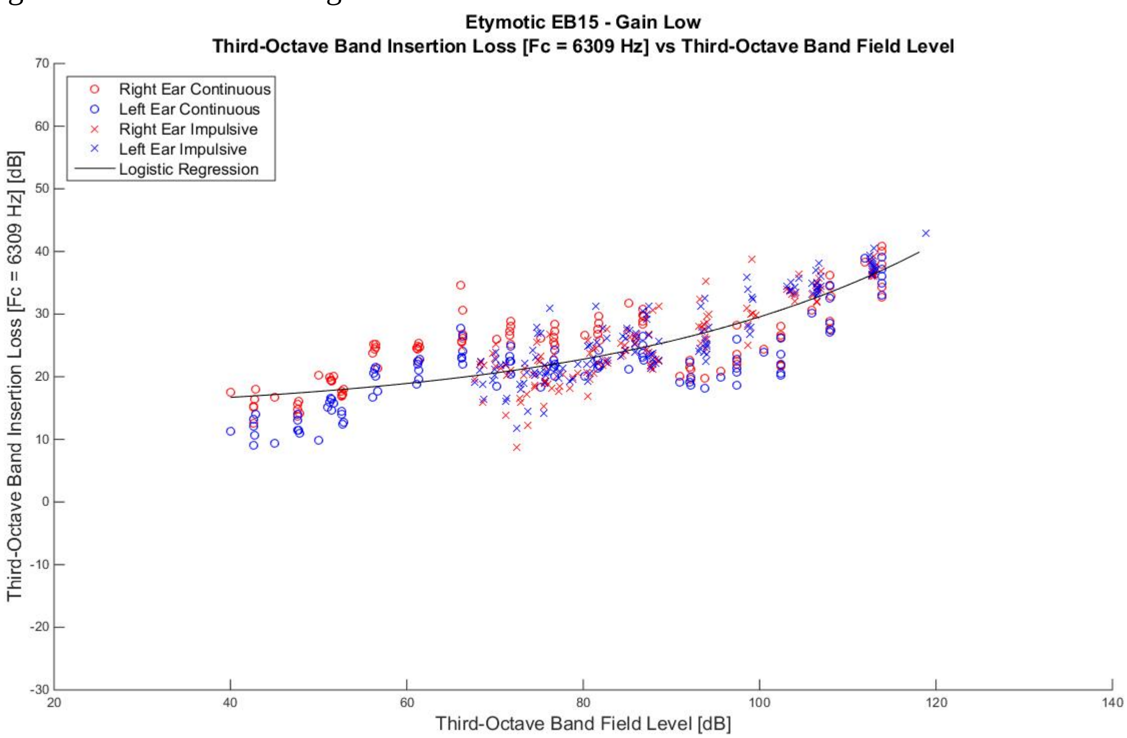

Figure A-243. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

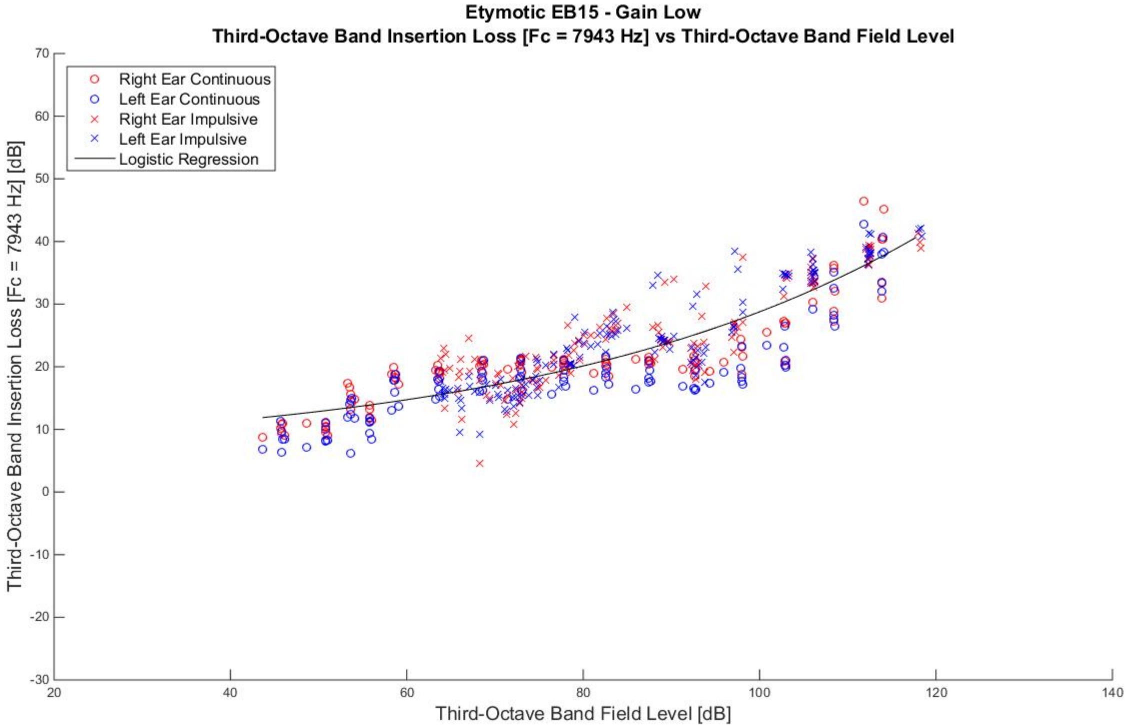

Figure A-244. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

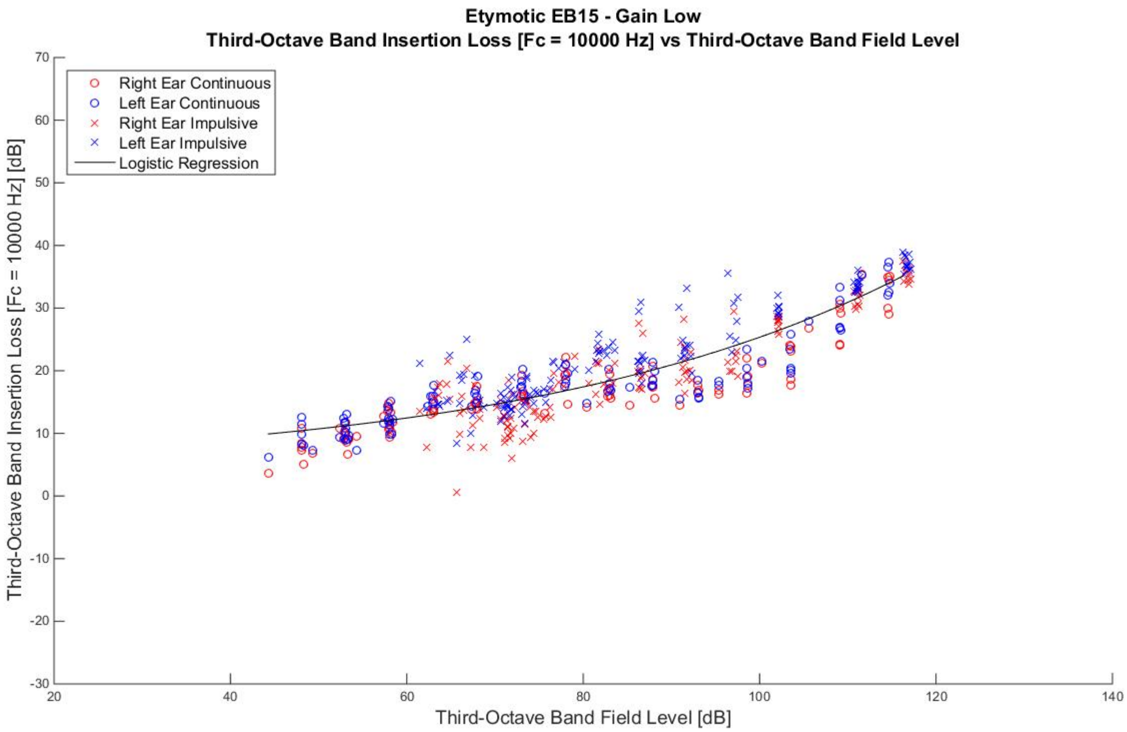

Figure A-245. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

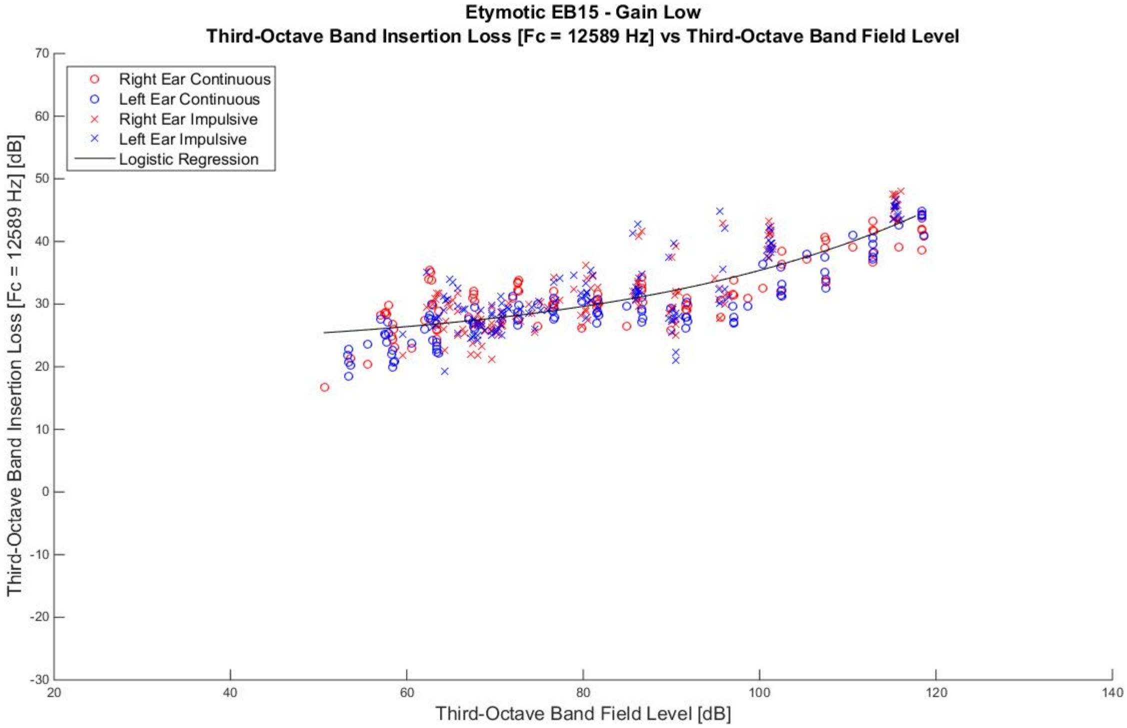

Figure A-246. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

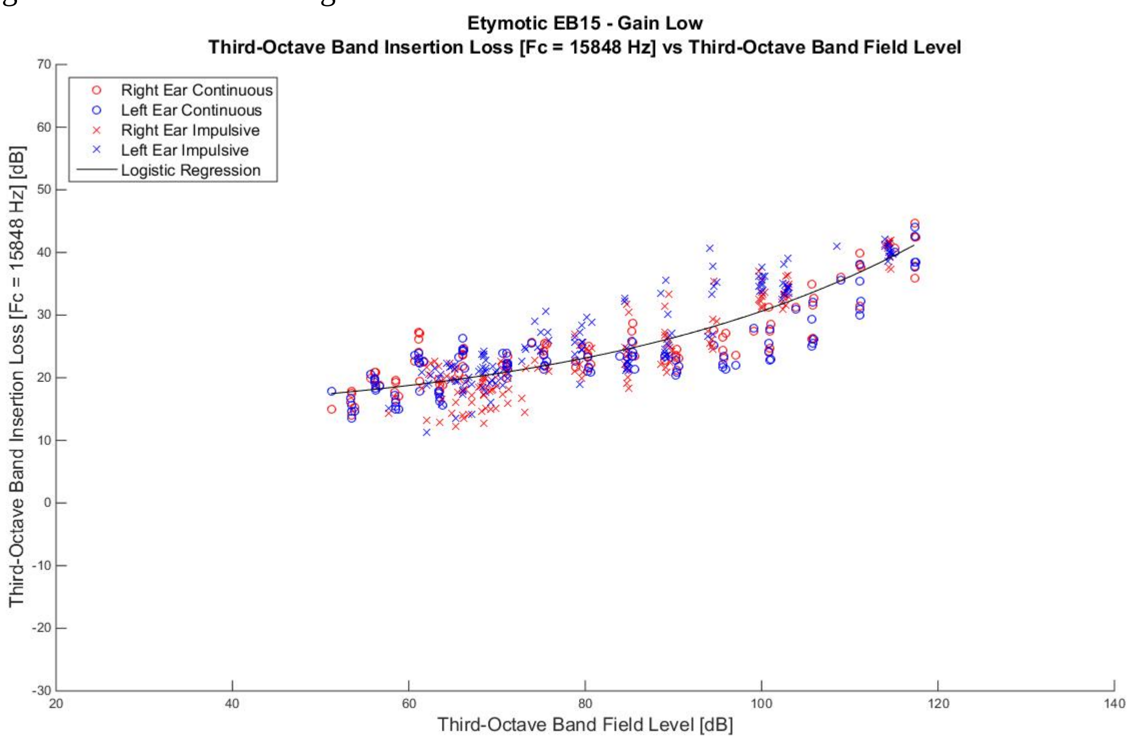

Figure A-247. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

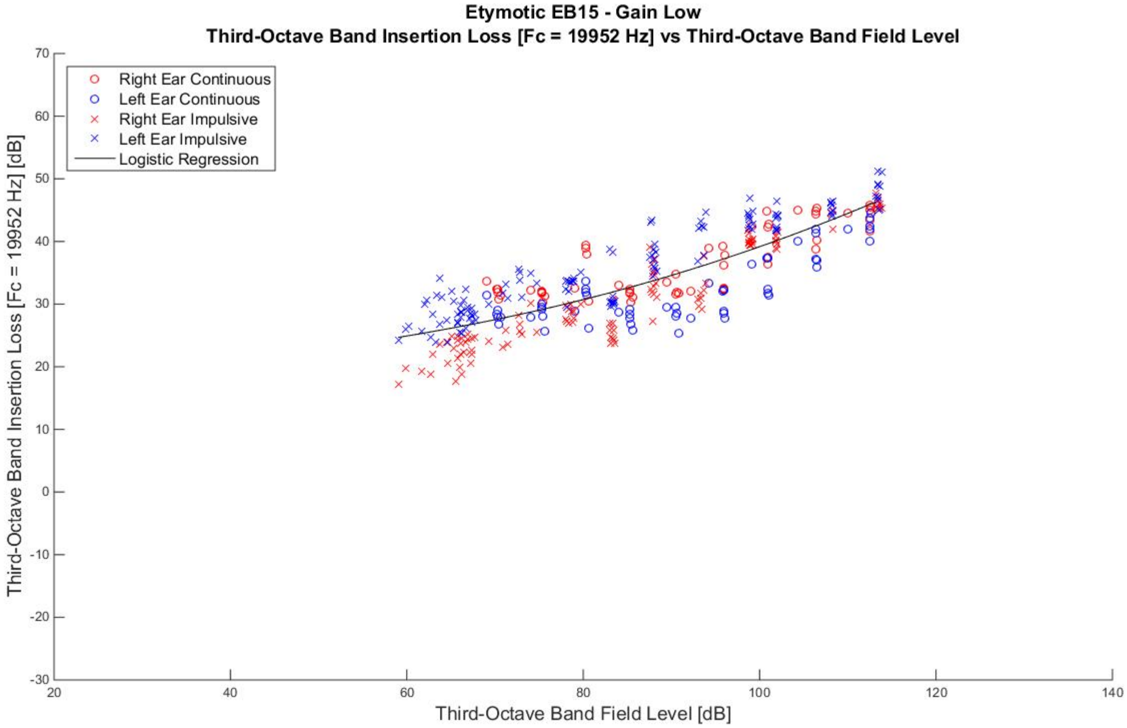

Figure A-248. EB15 - low gain - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

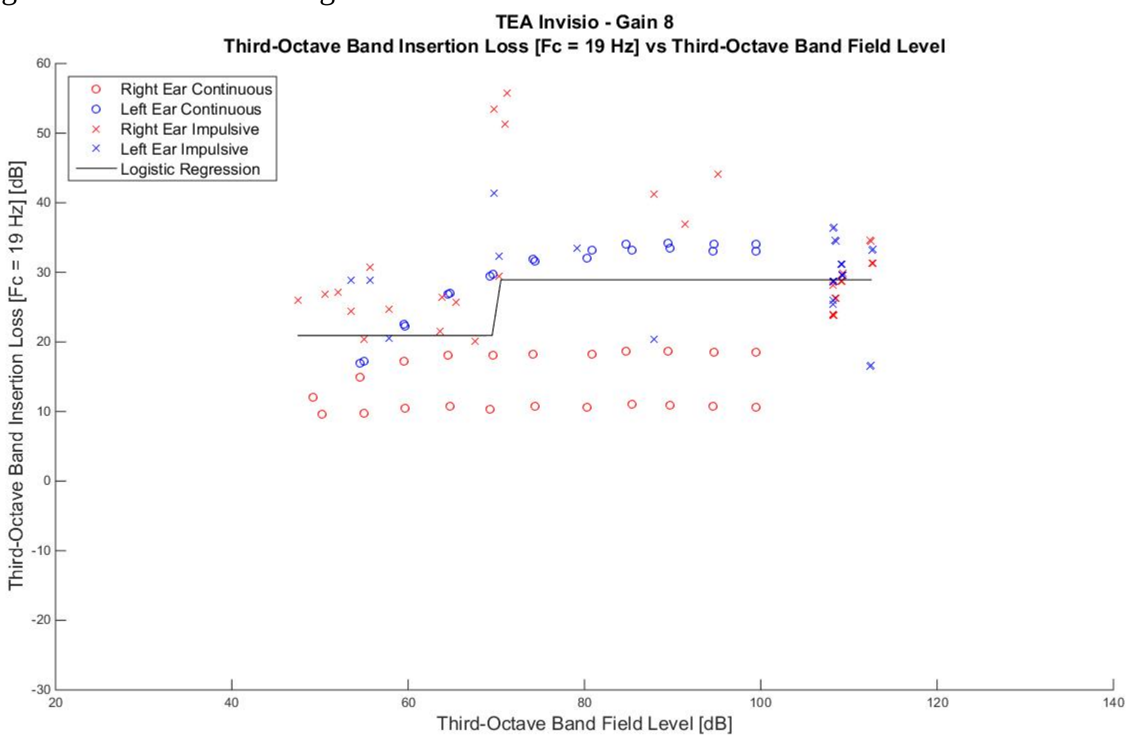

Figure A-249. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

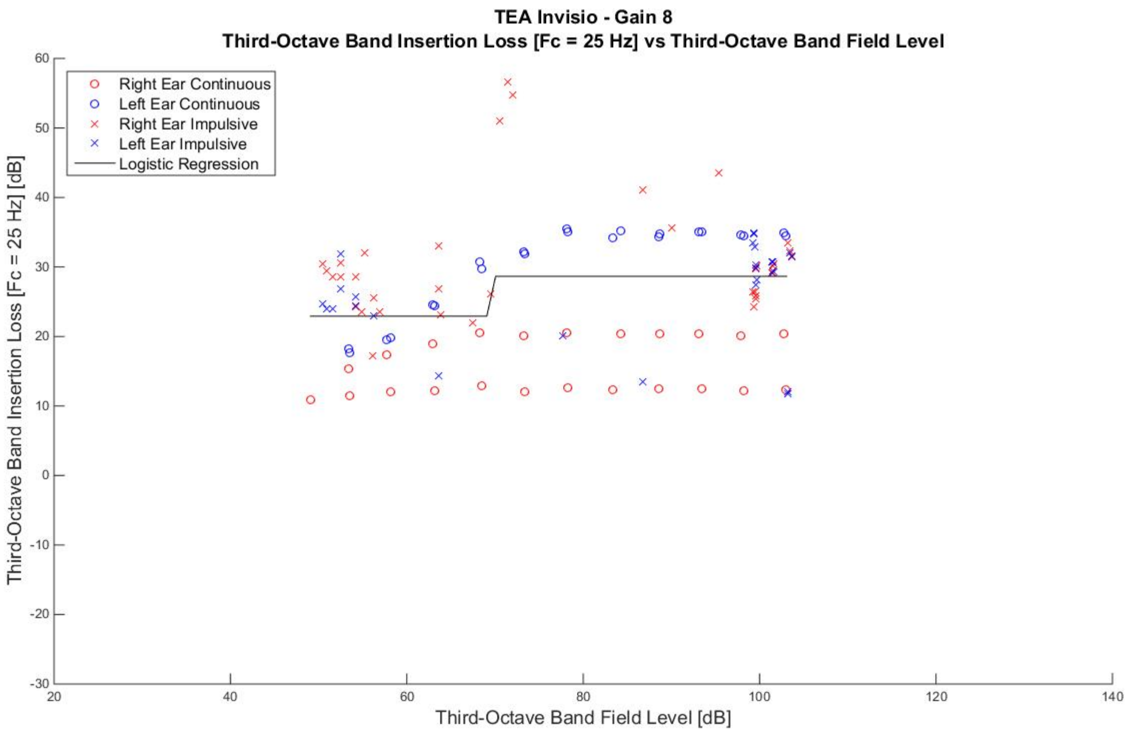

Figure A-250. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

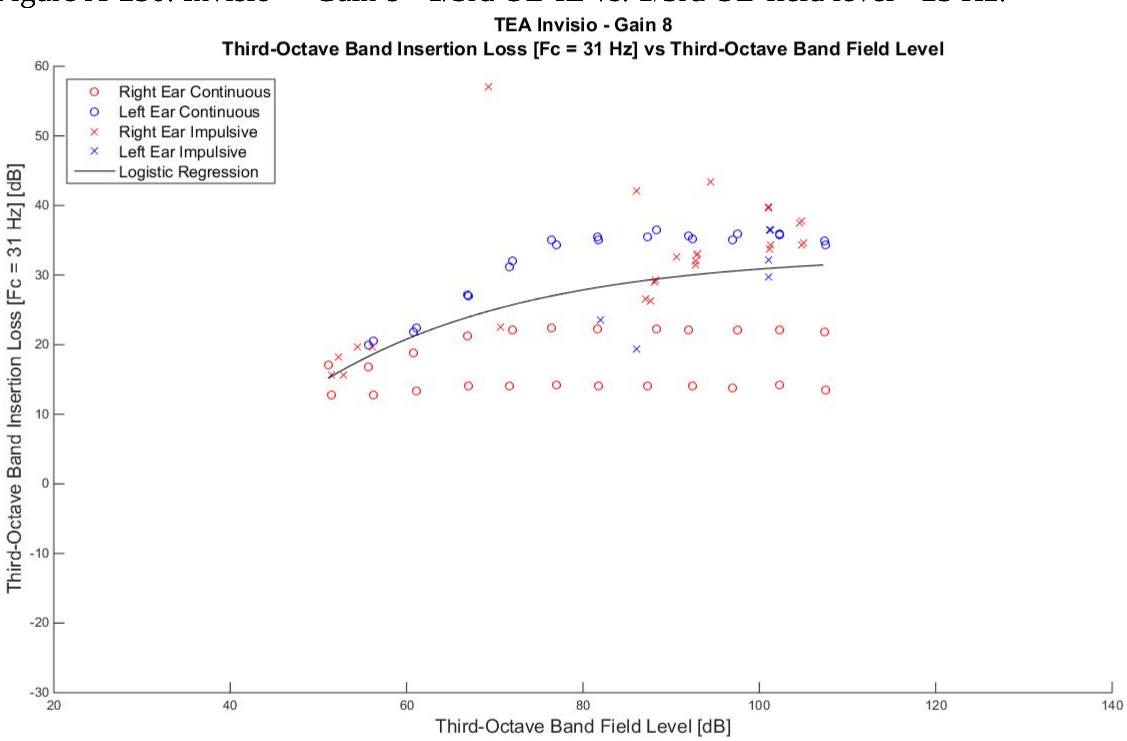

Figure A-251. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

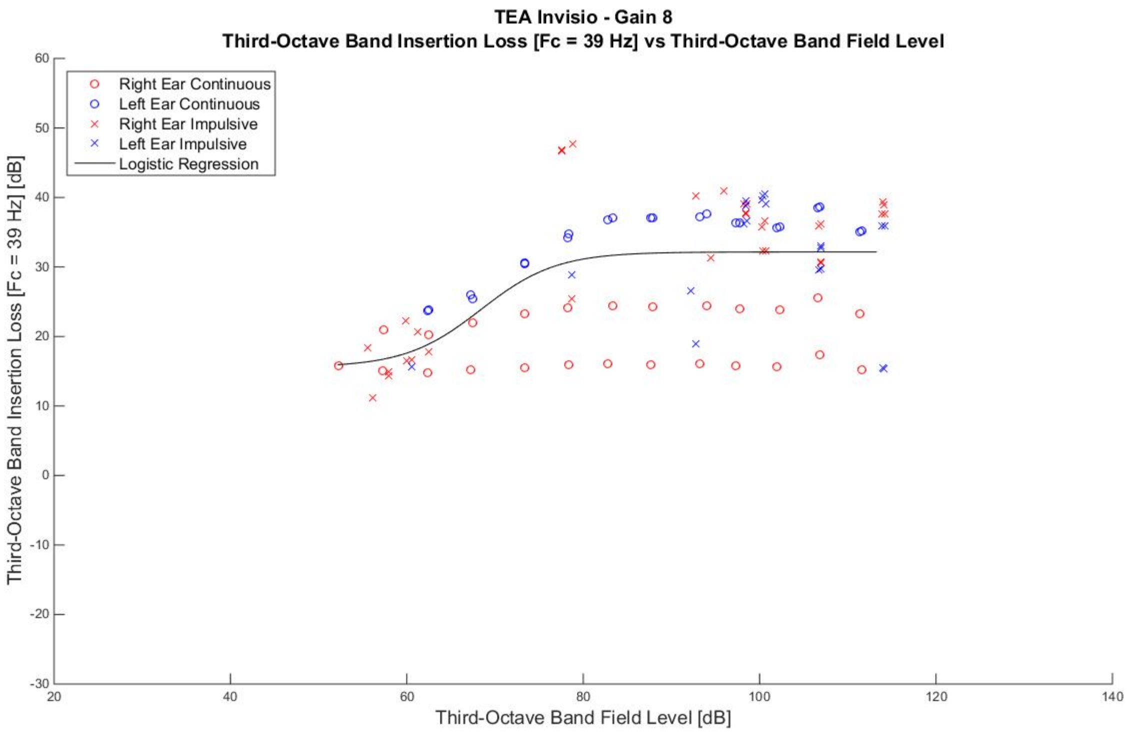

Figure A-252. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

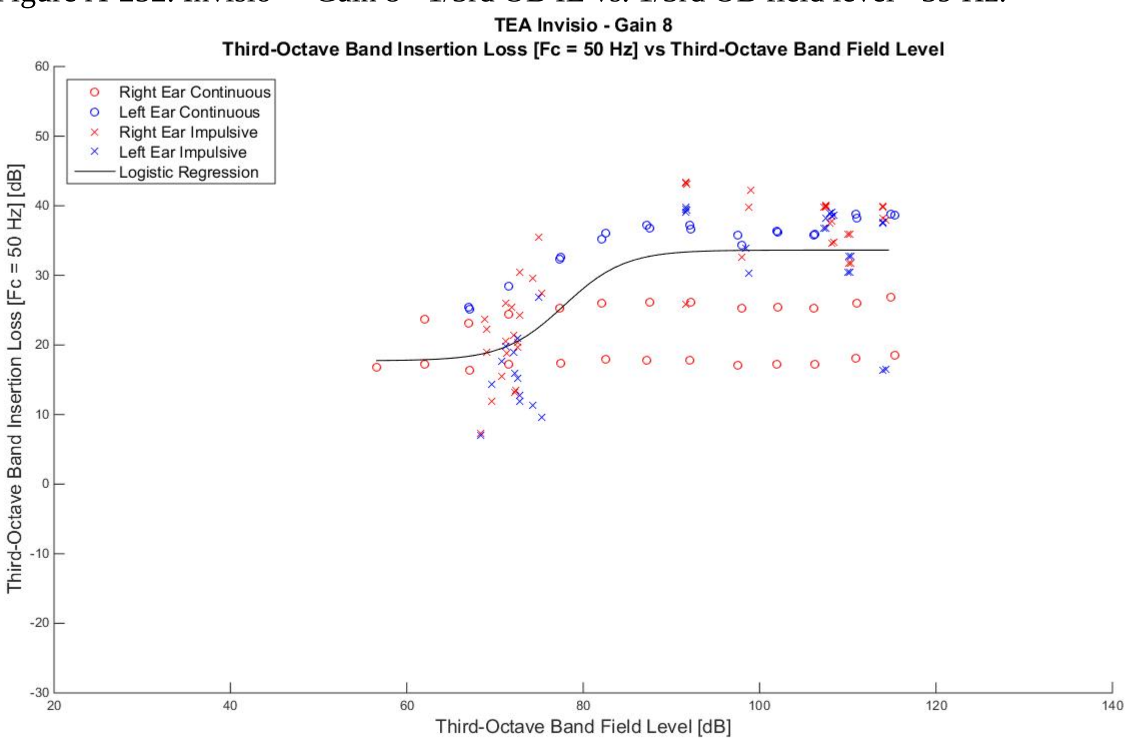

Figure A-253. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

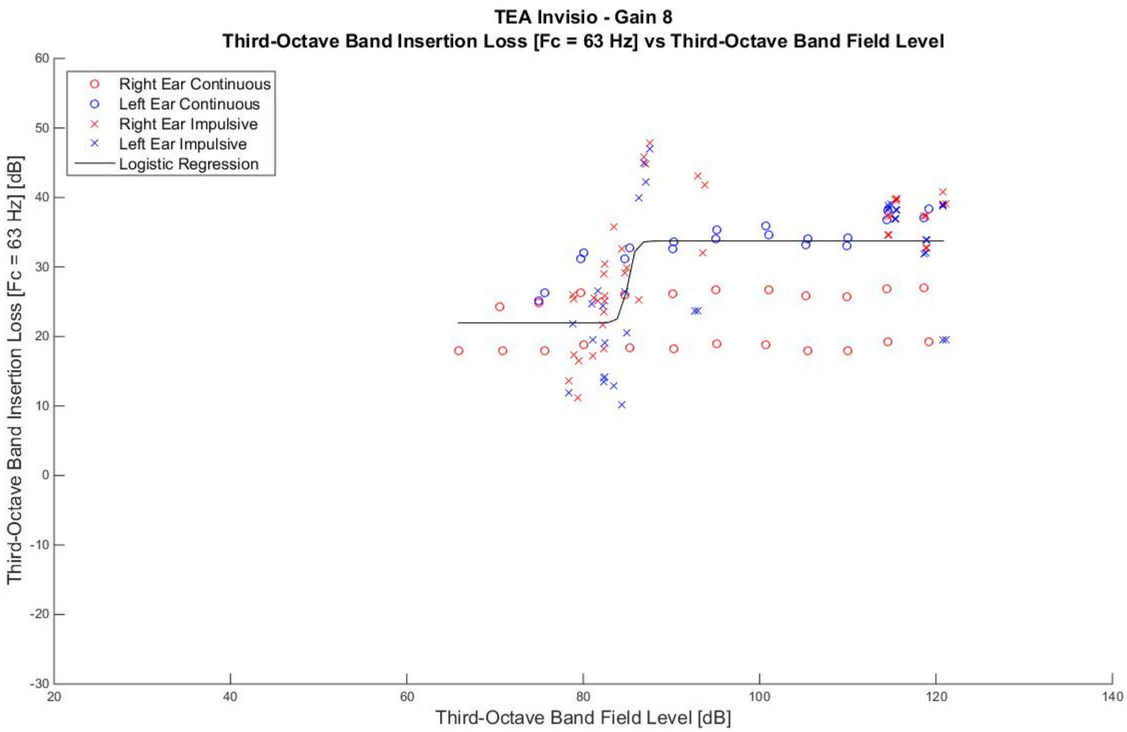

Figure A-254. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

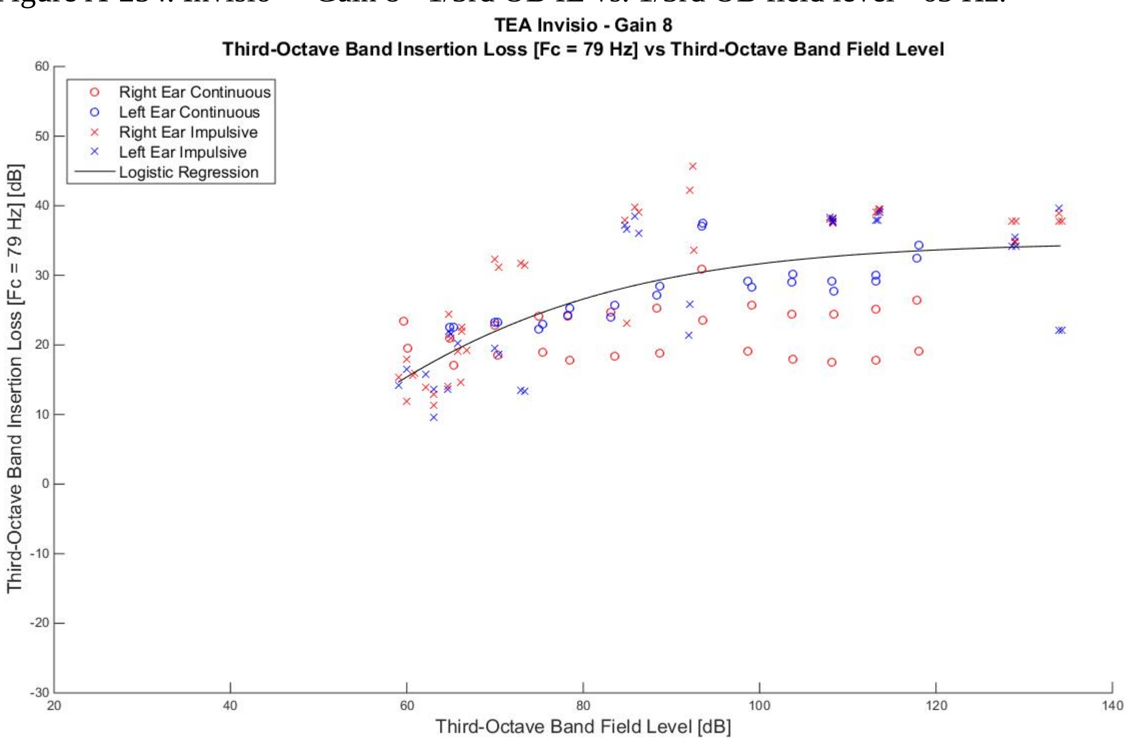

Figure A-255. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

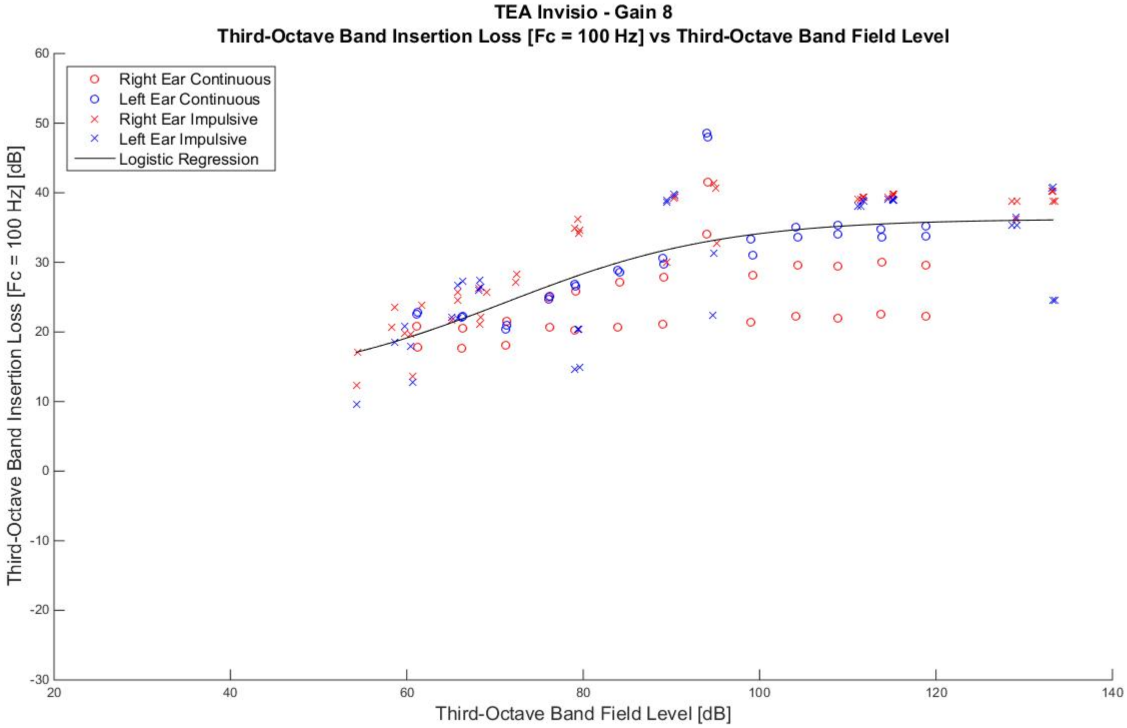

Figure A-256. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

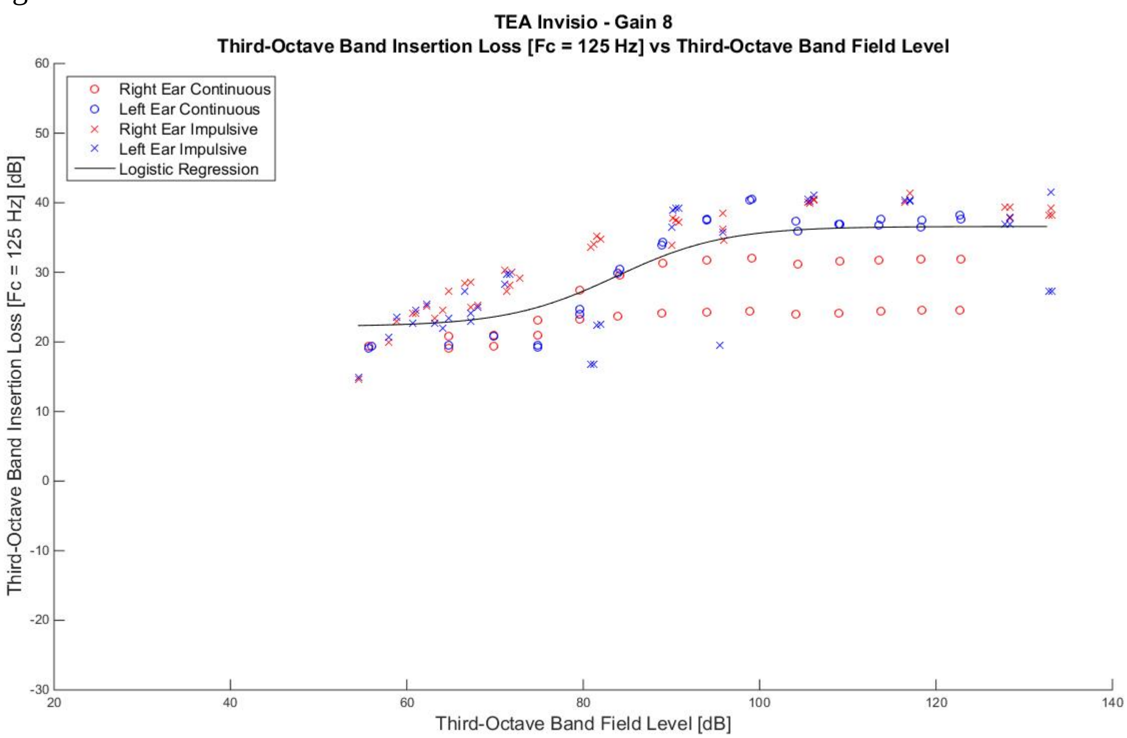

Figure A-257. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

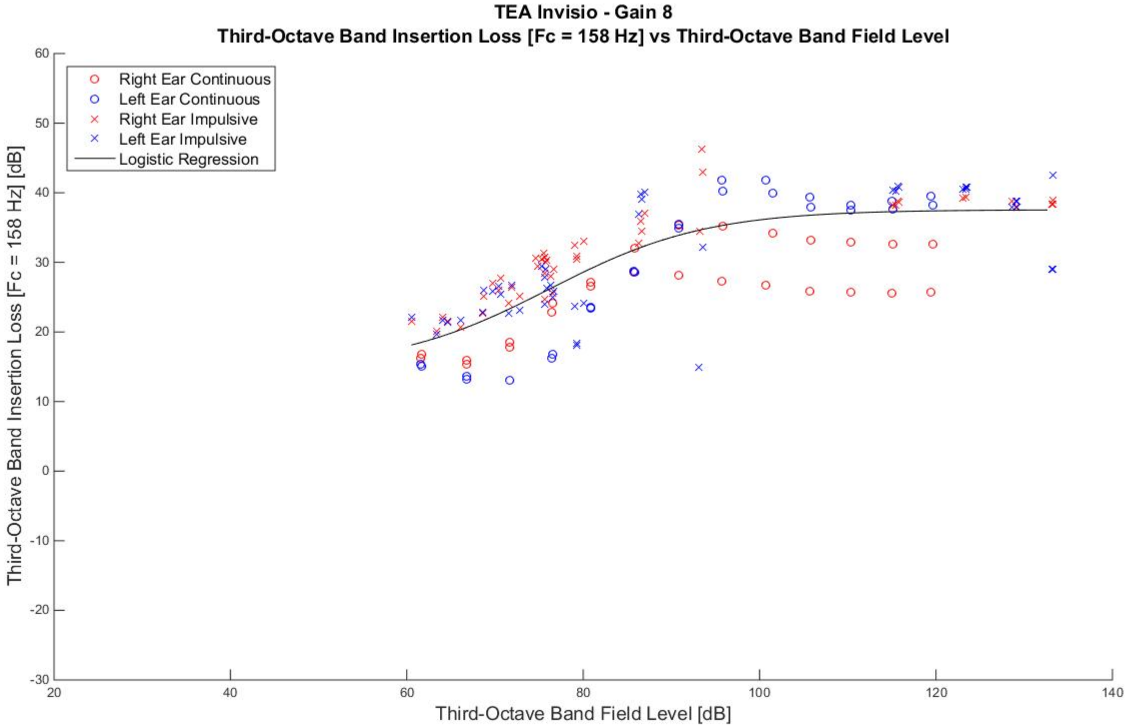

Figure A-258. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

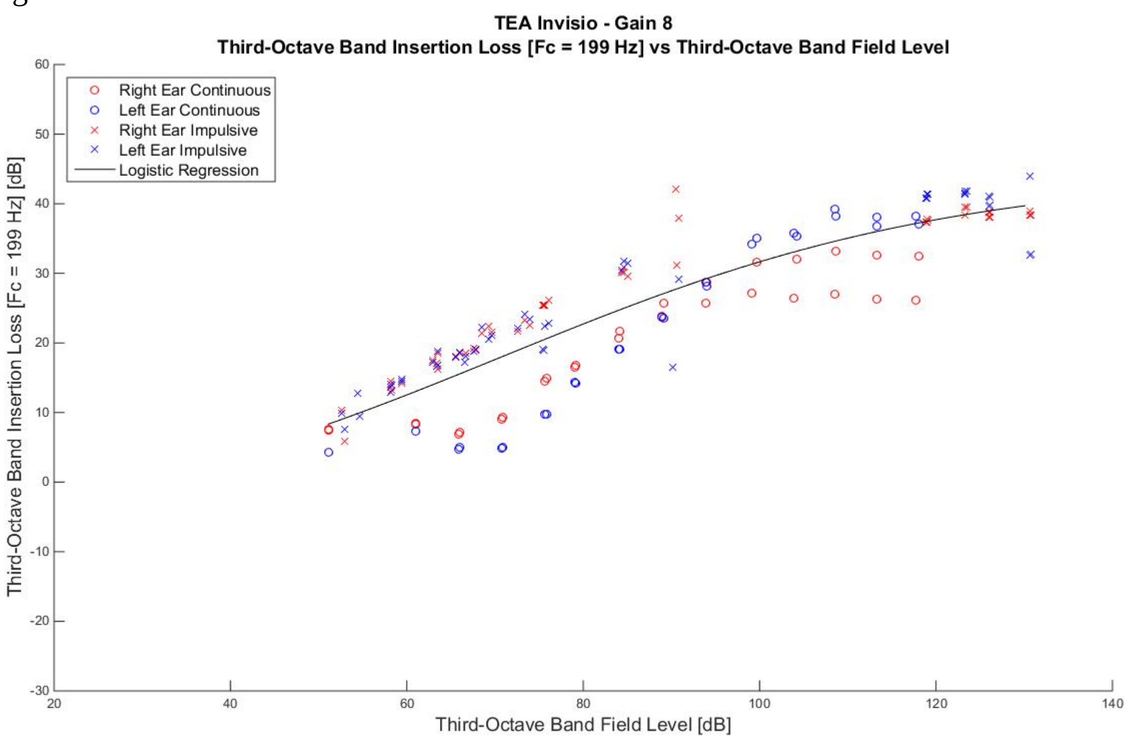

Figure A-259. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

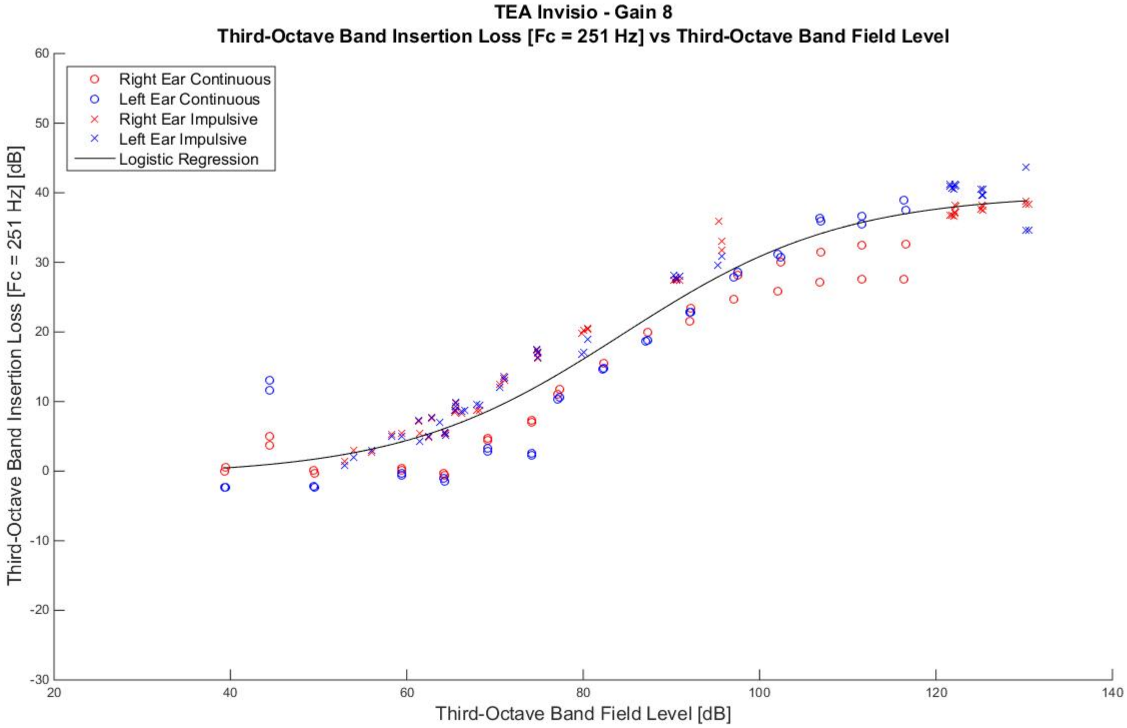

Figure A-260. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

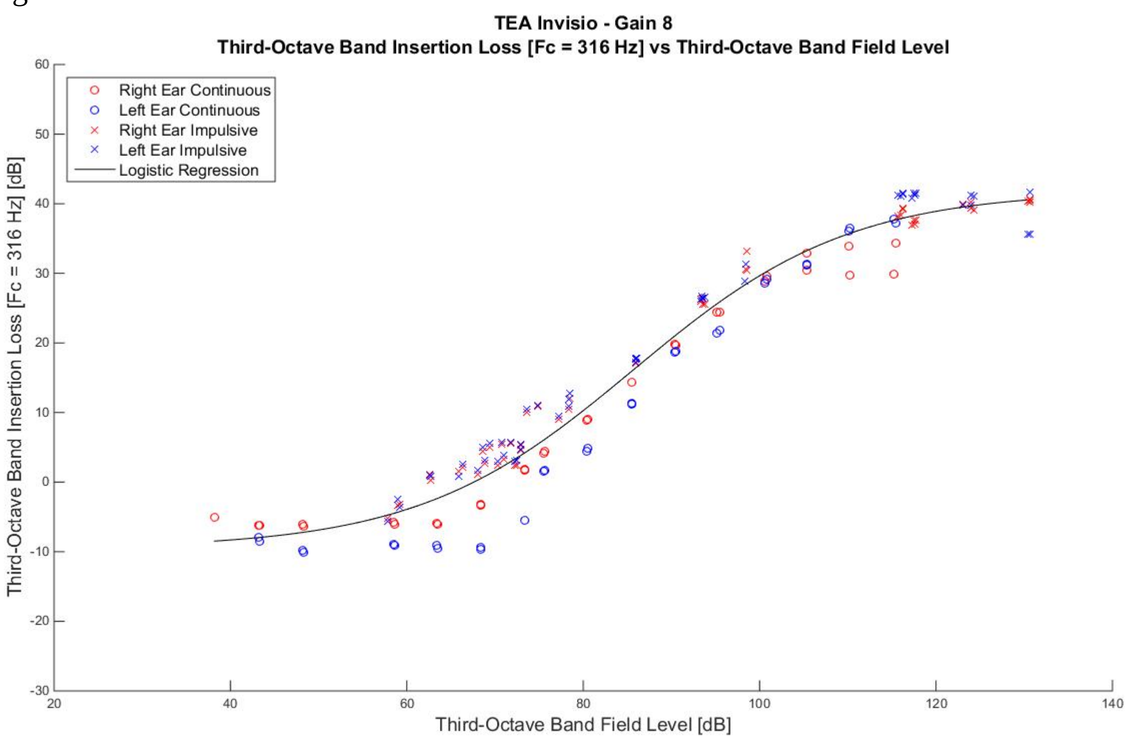

Figure A-261. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

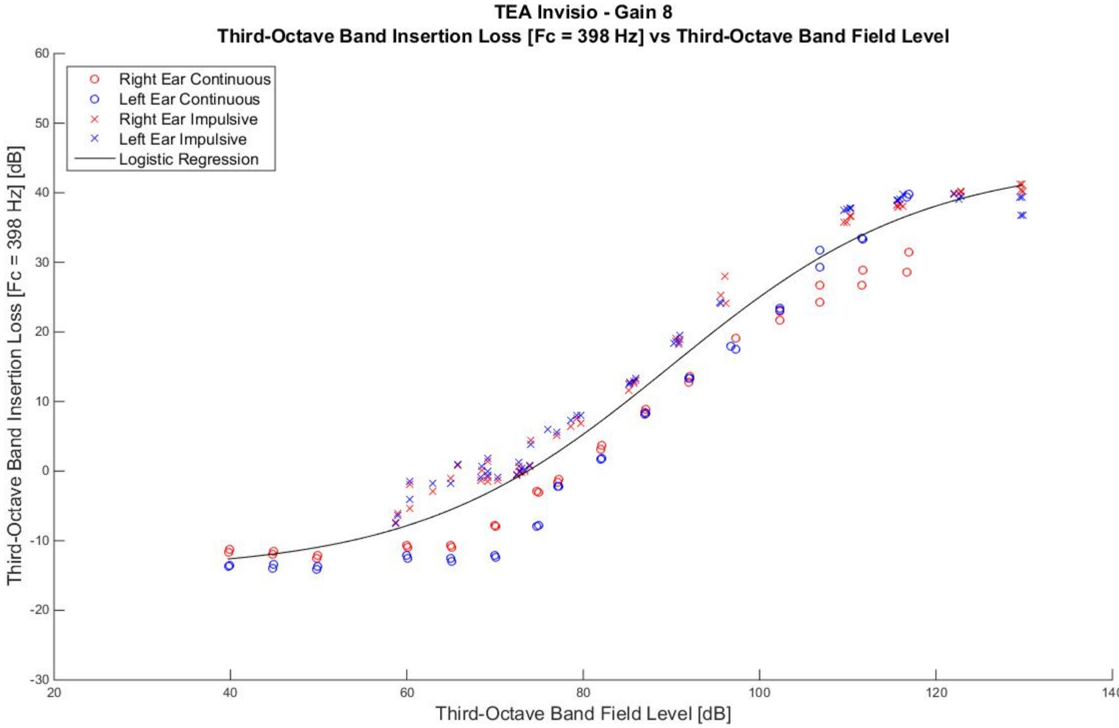

Figure A-262. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

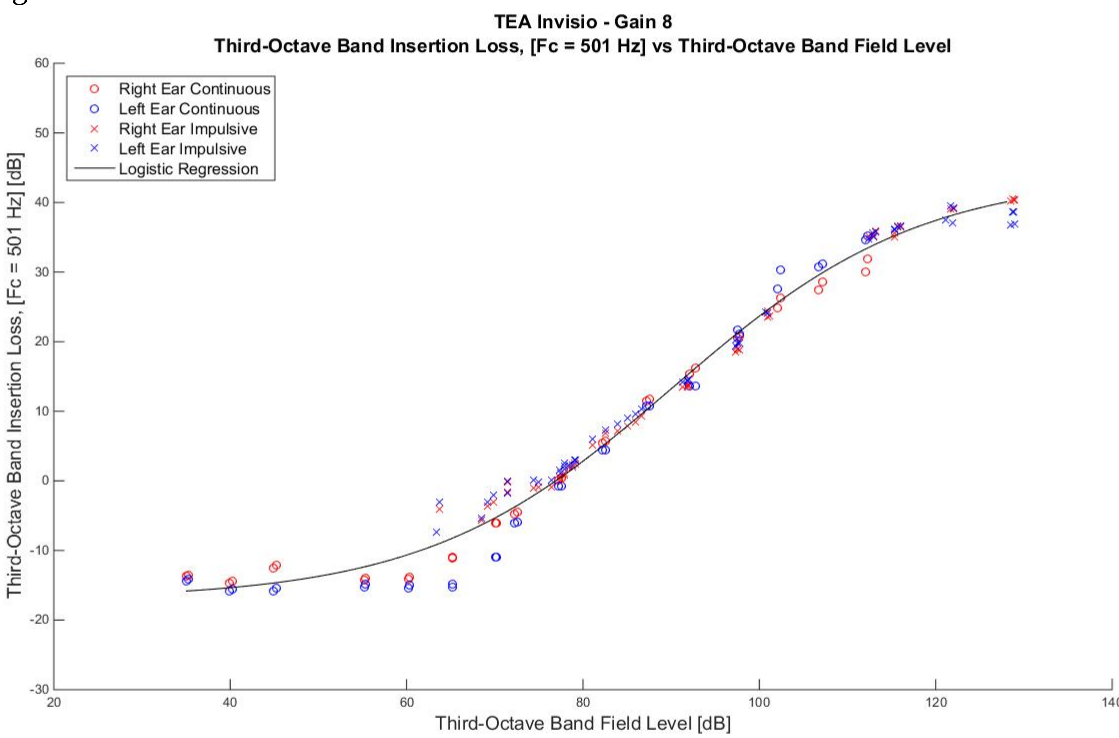

Figure A-263. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

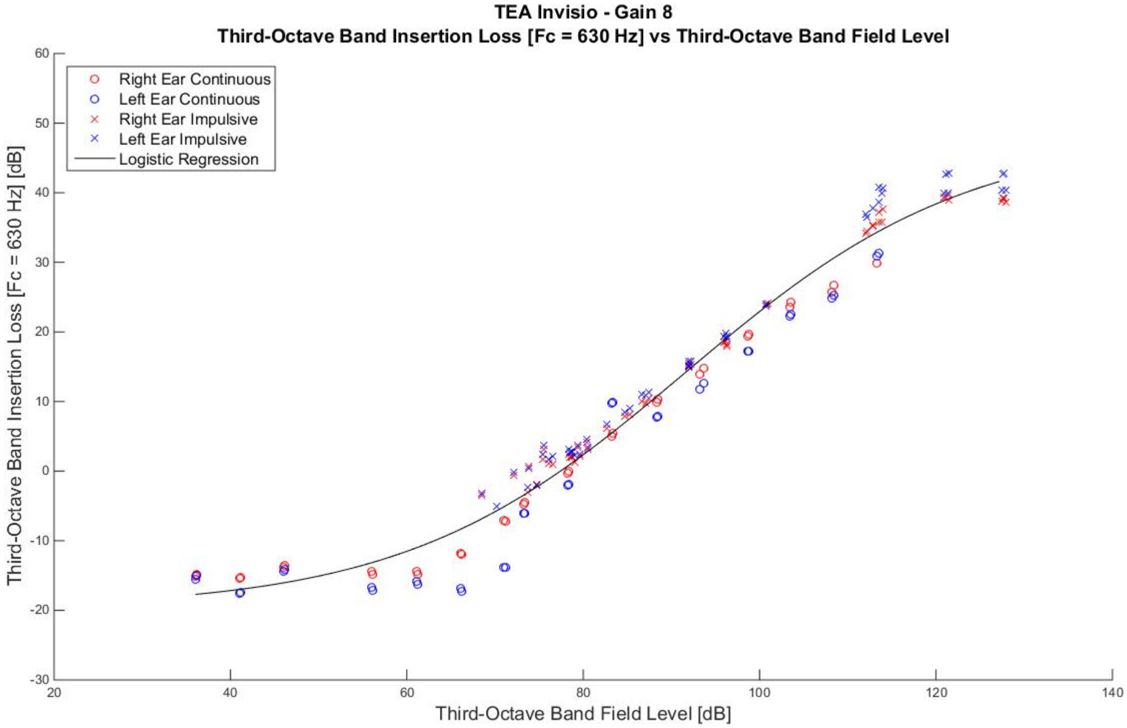

Figure A-264. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

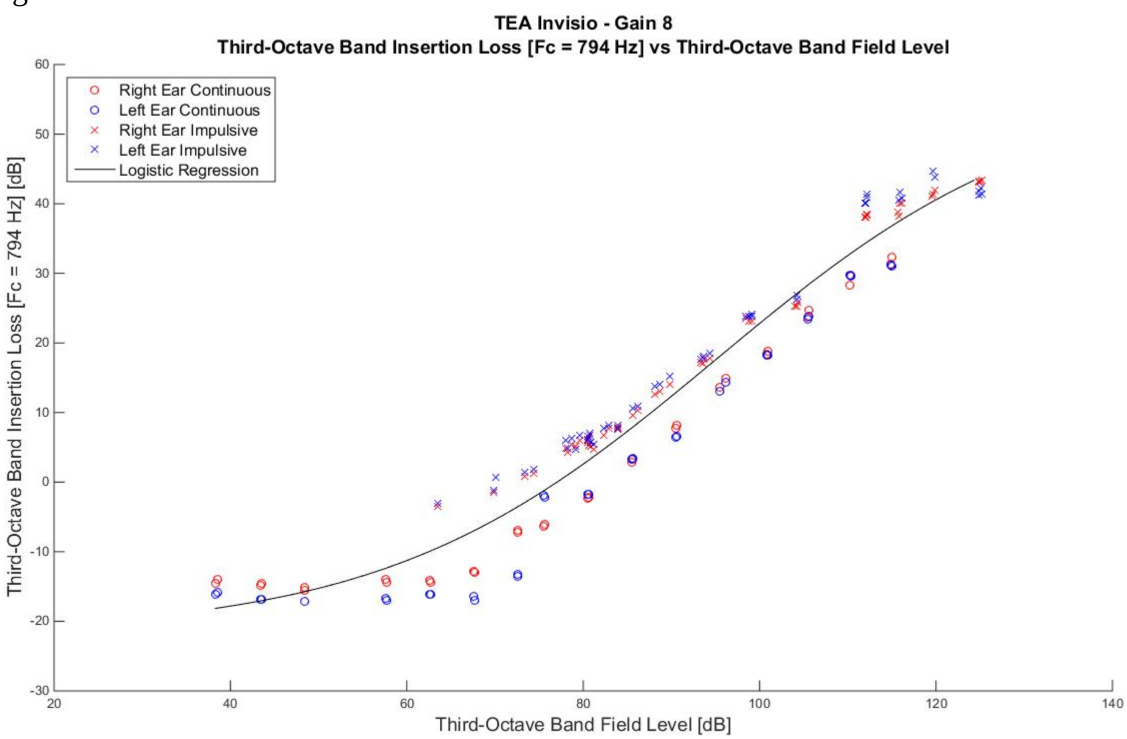

Figure A-265. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

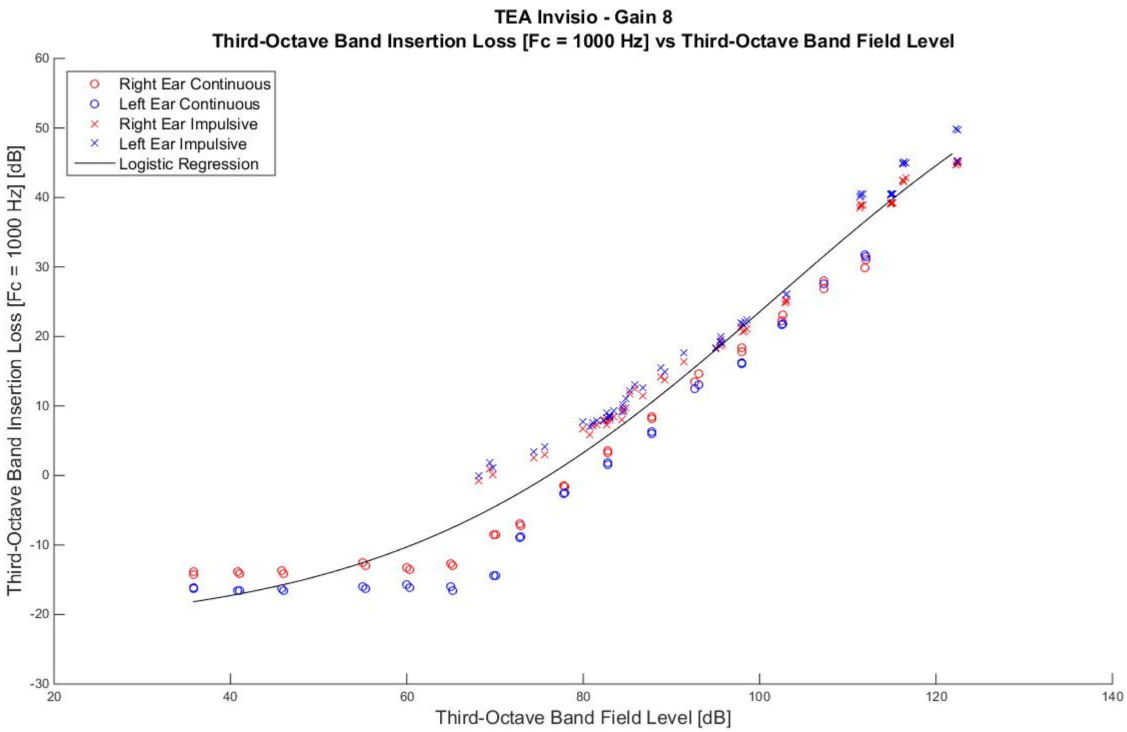

Figure A-266. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

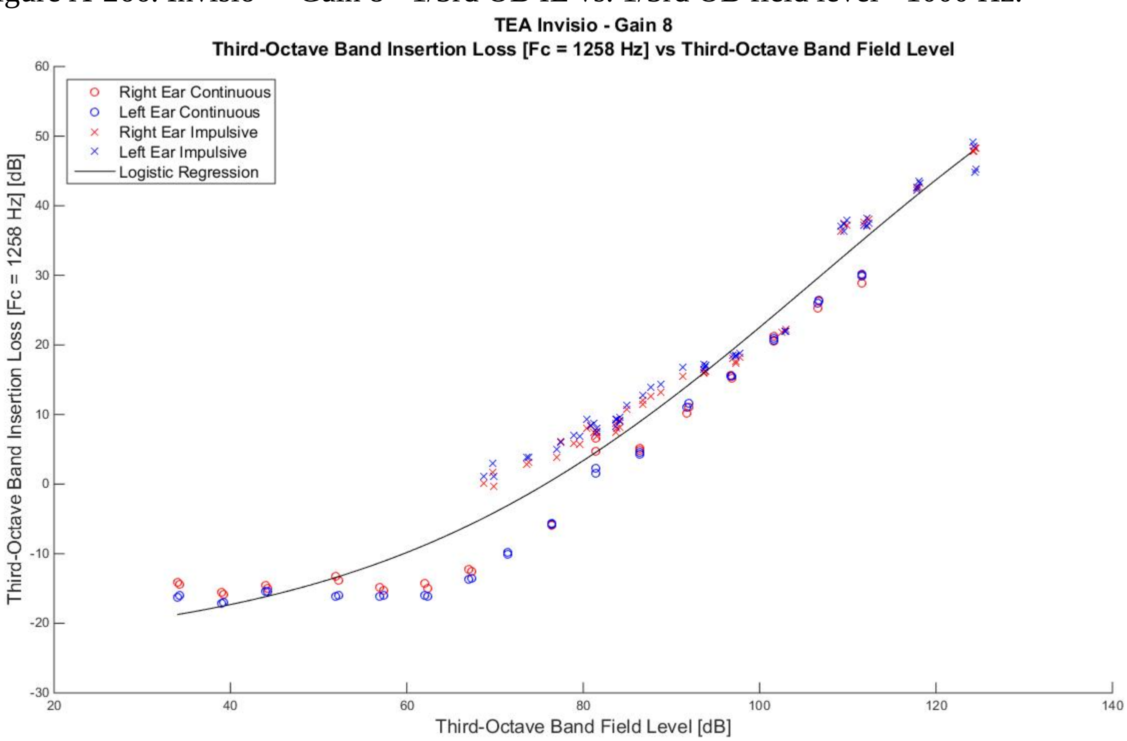

Figure A-267. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

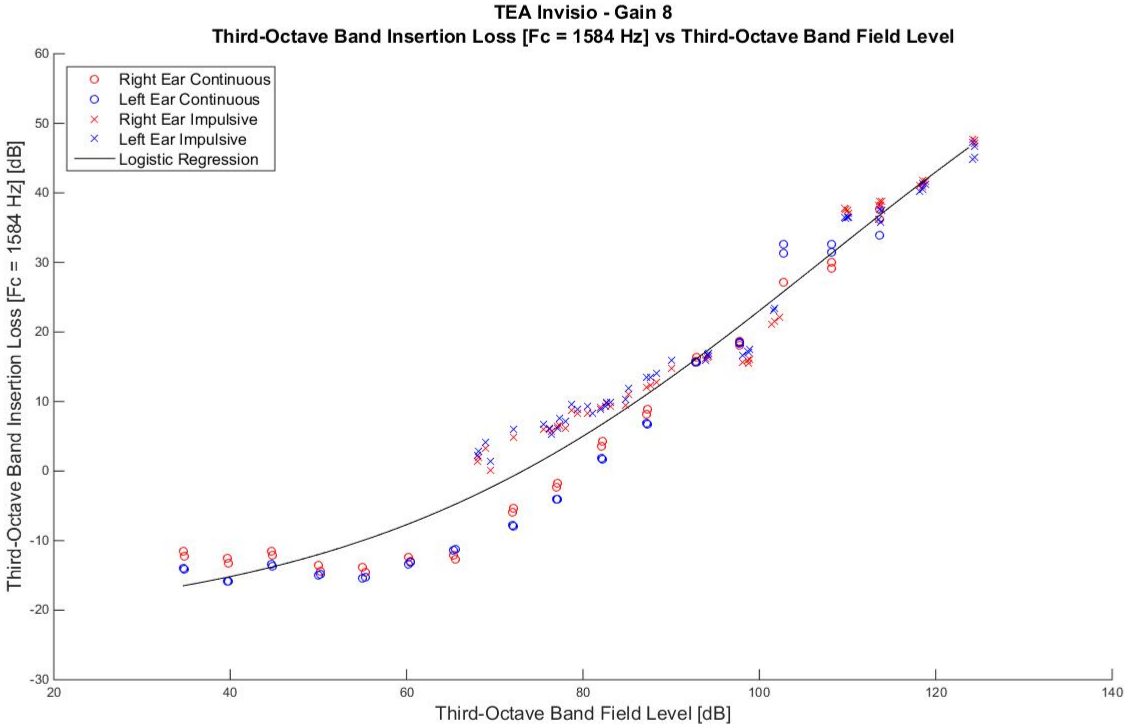

Figure A-268. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

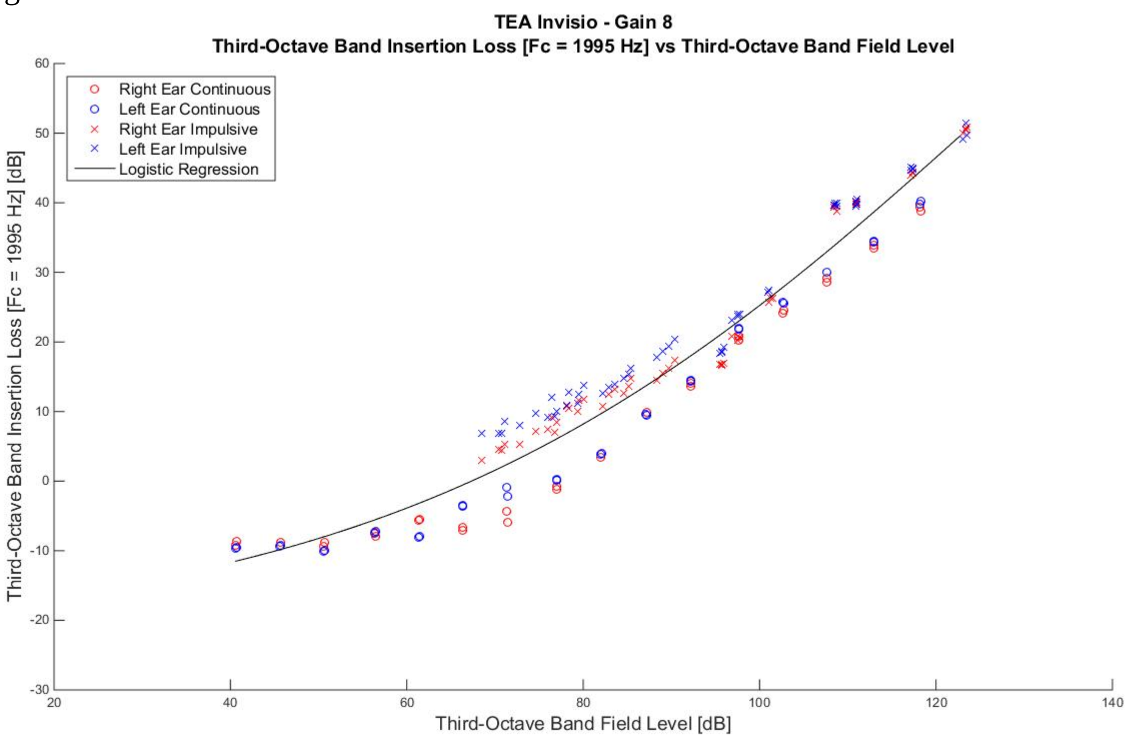

Figure A-269. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

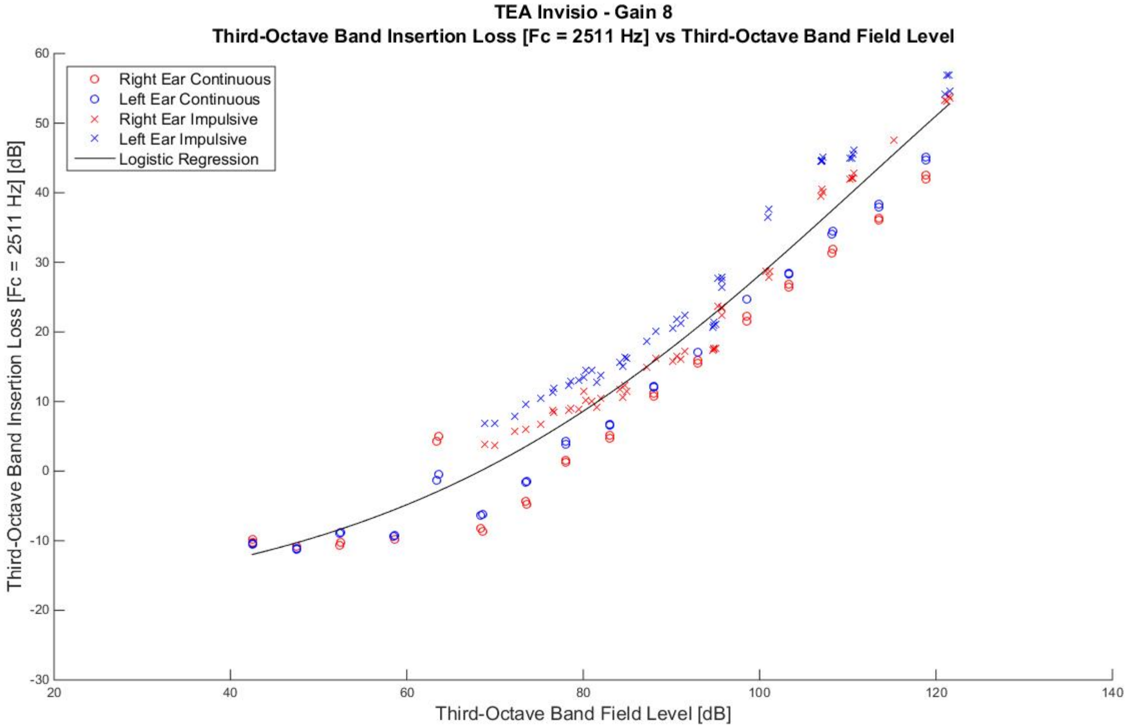

Figure A-270. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

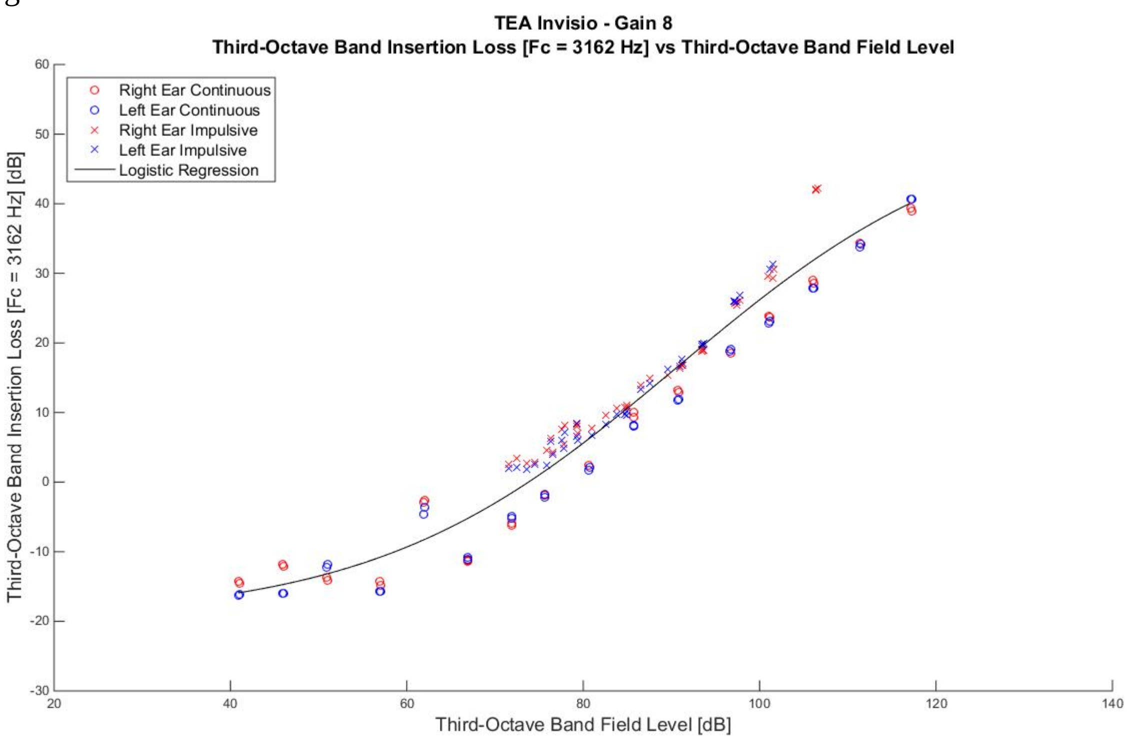

Figure A-271. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

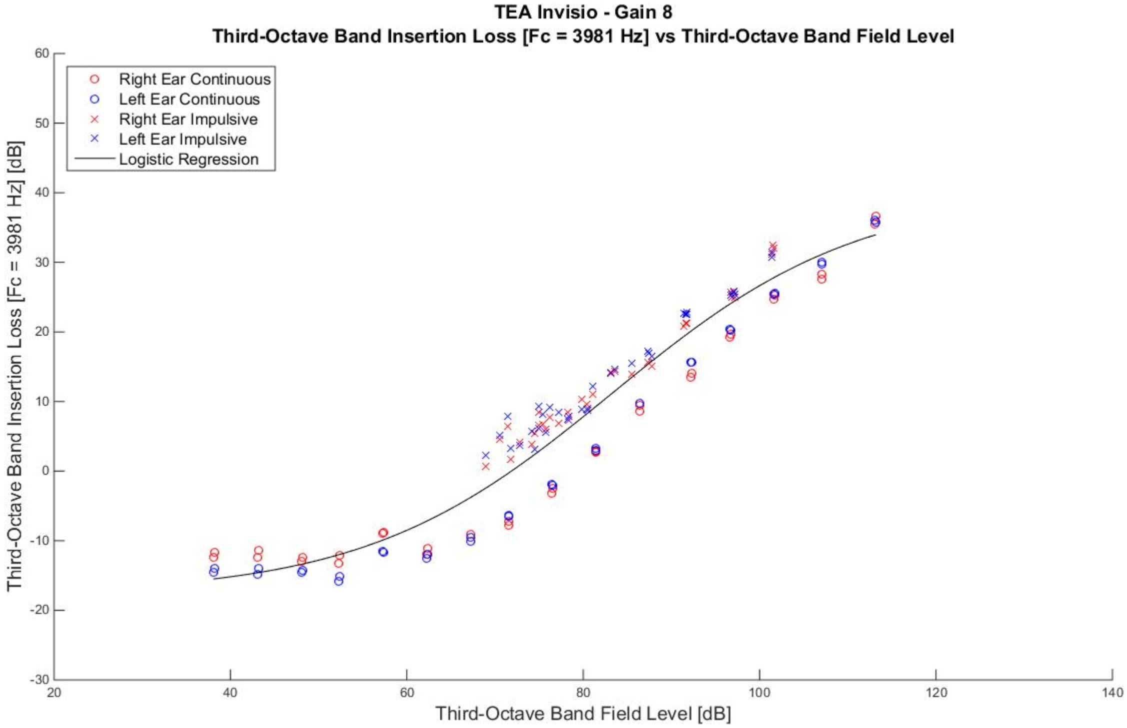

Figure A-272. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

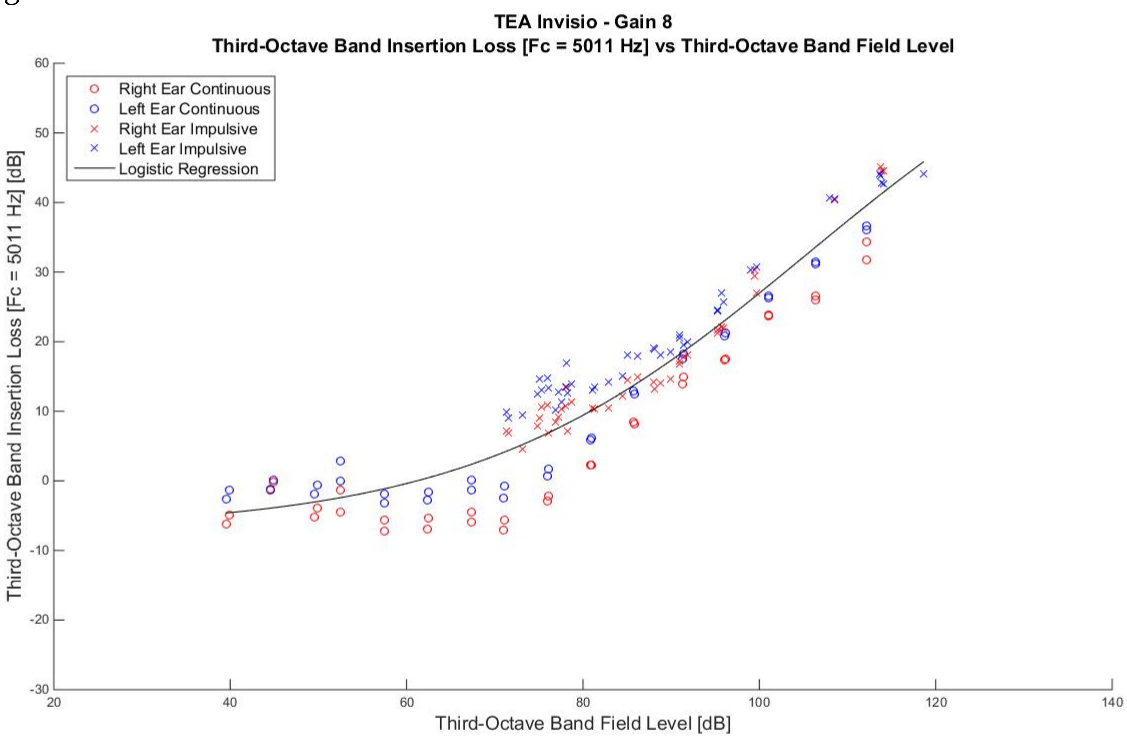

Figure A-273. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

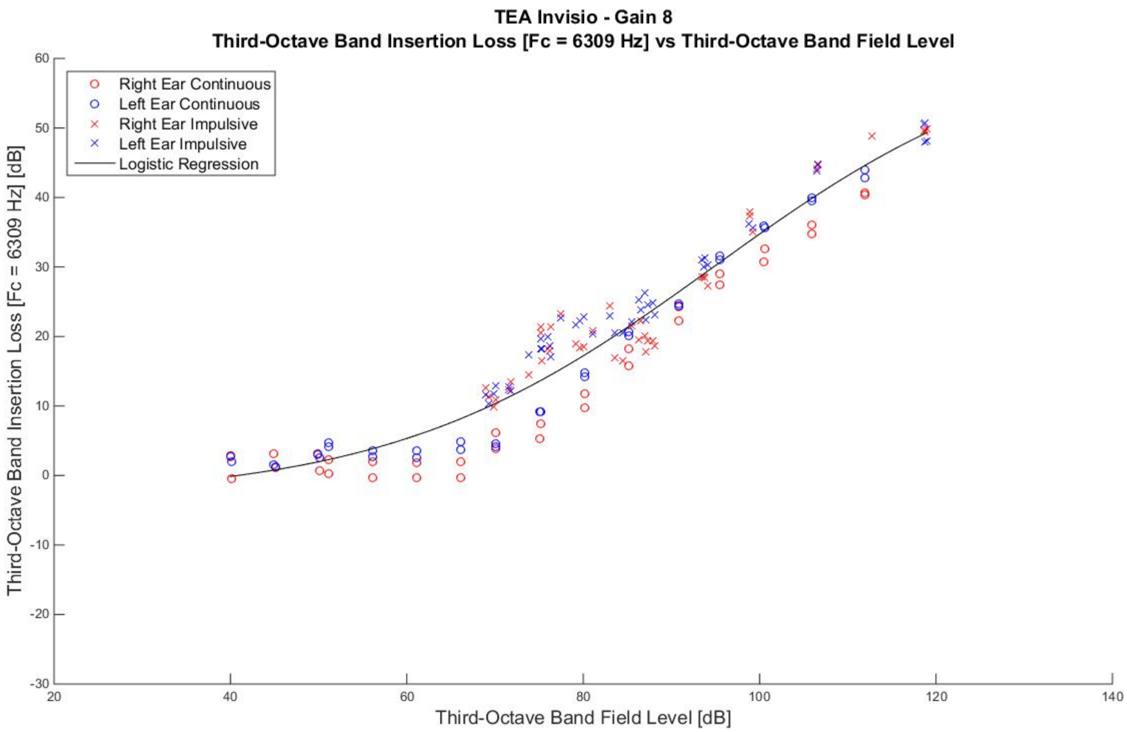

Figure A-274. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

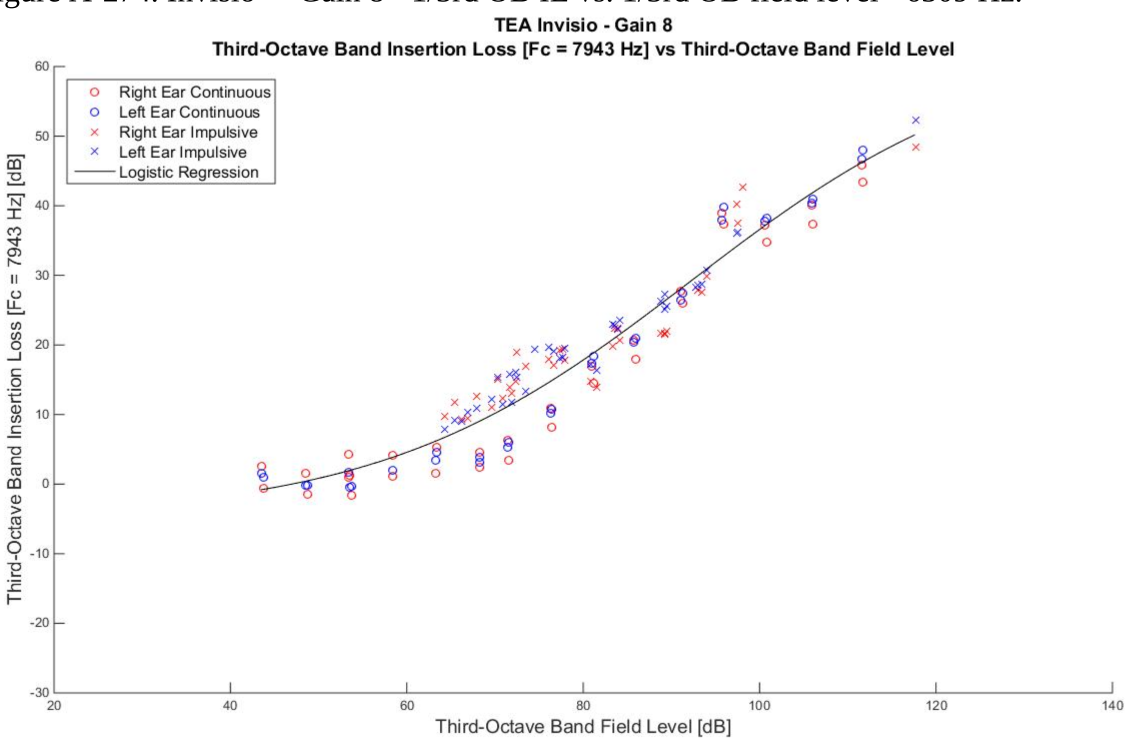

Figure A-275. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

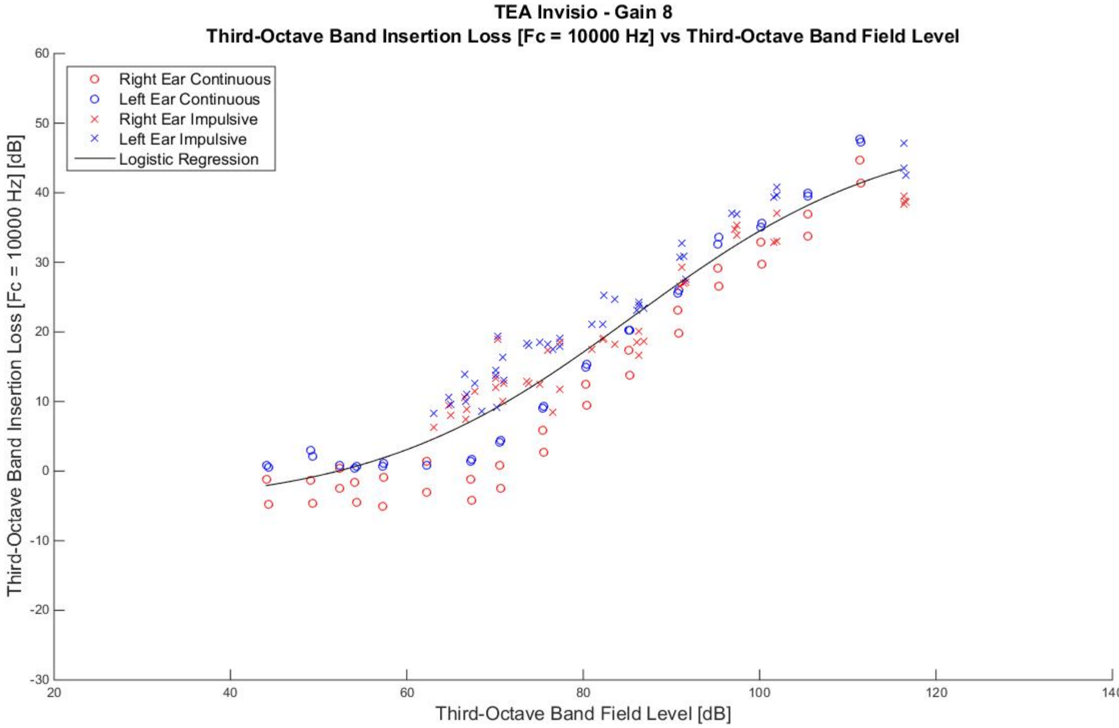

Figure A-276. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

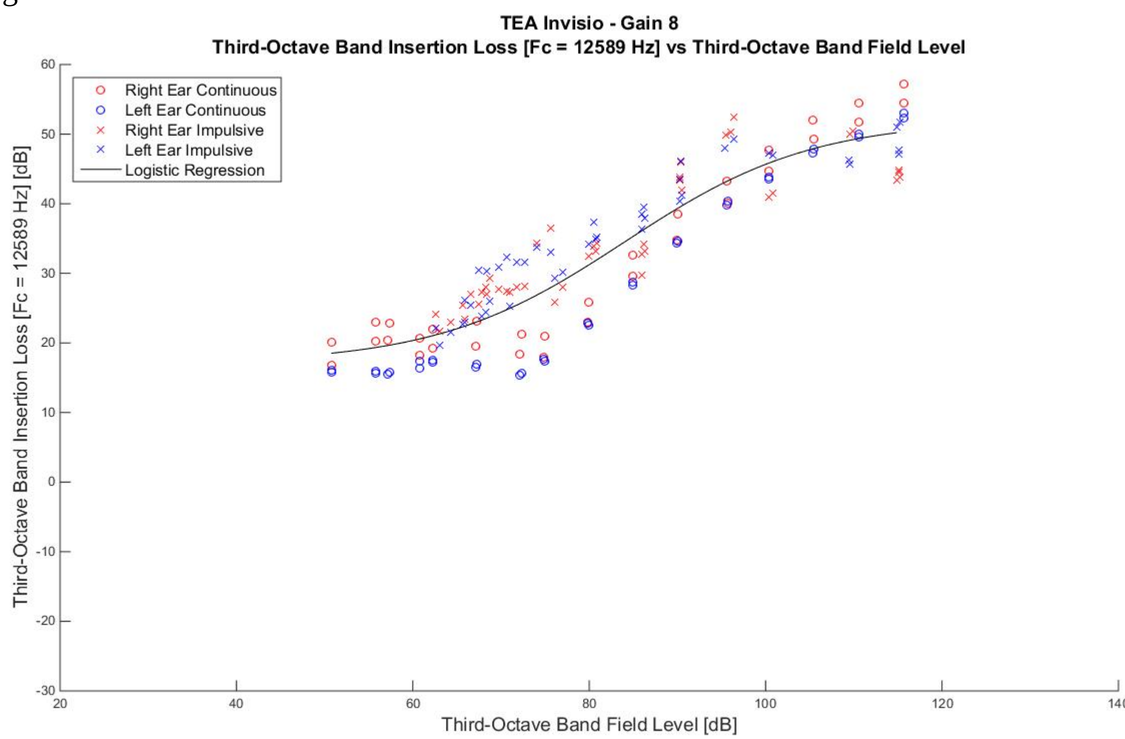

Figure A-277. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

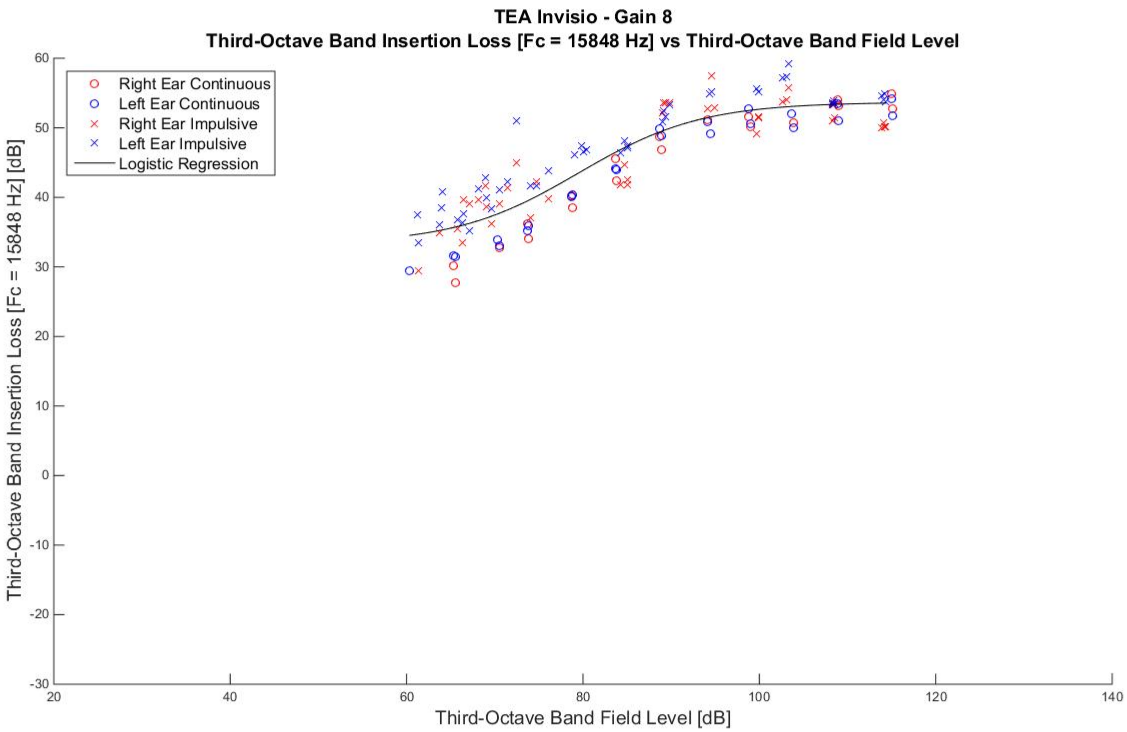

Figure A-278. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

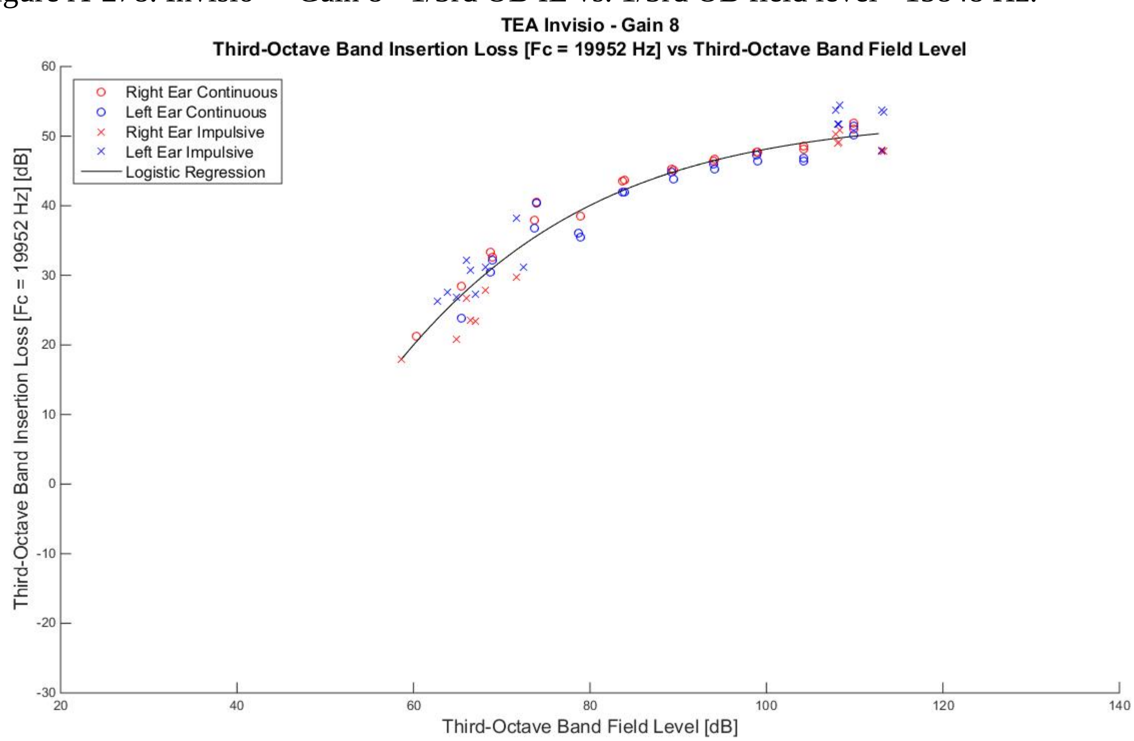

Figure A-279. Invisio® - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

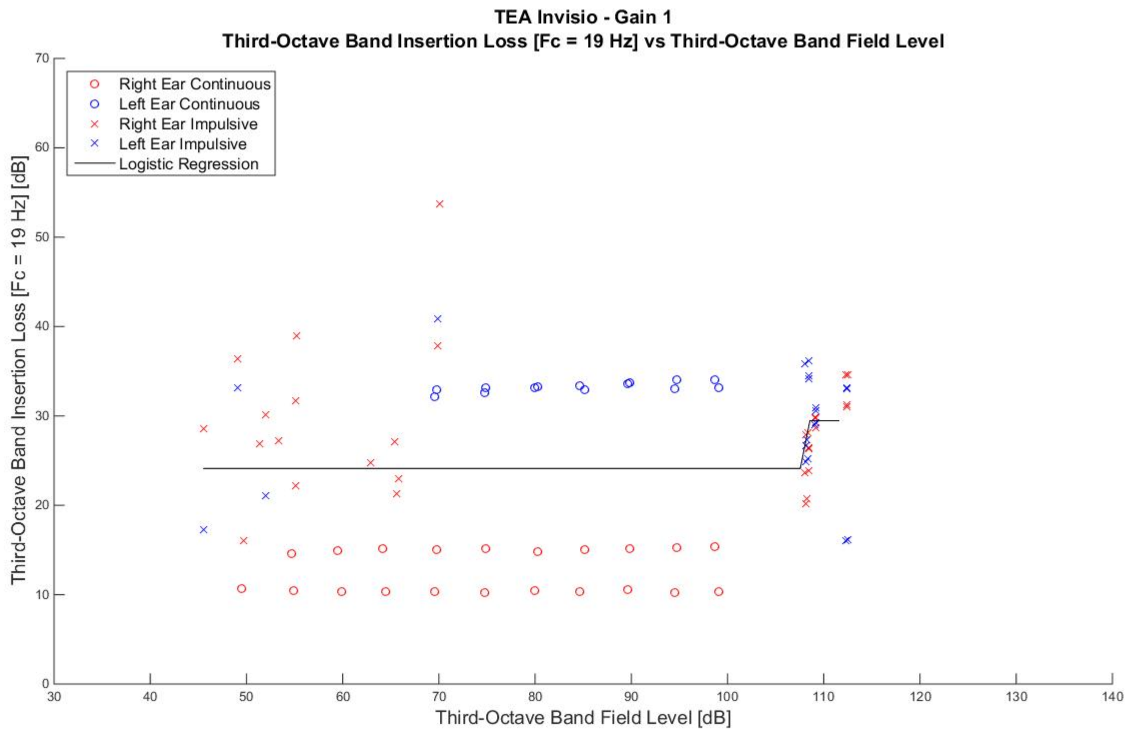

Figure A-280. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

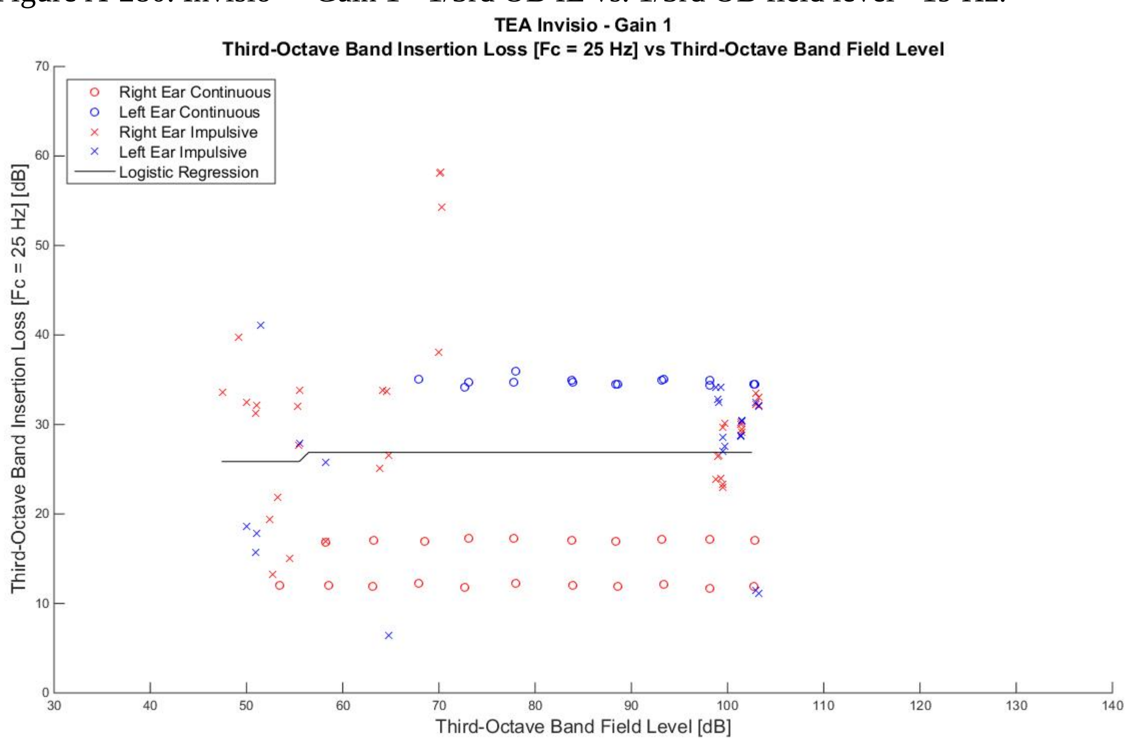

Figure A-281. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

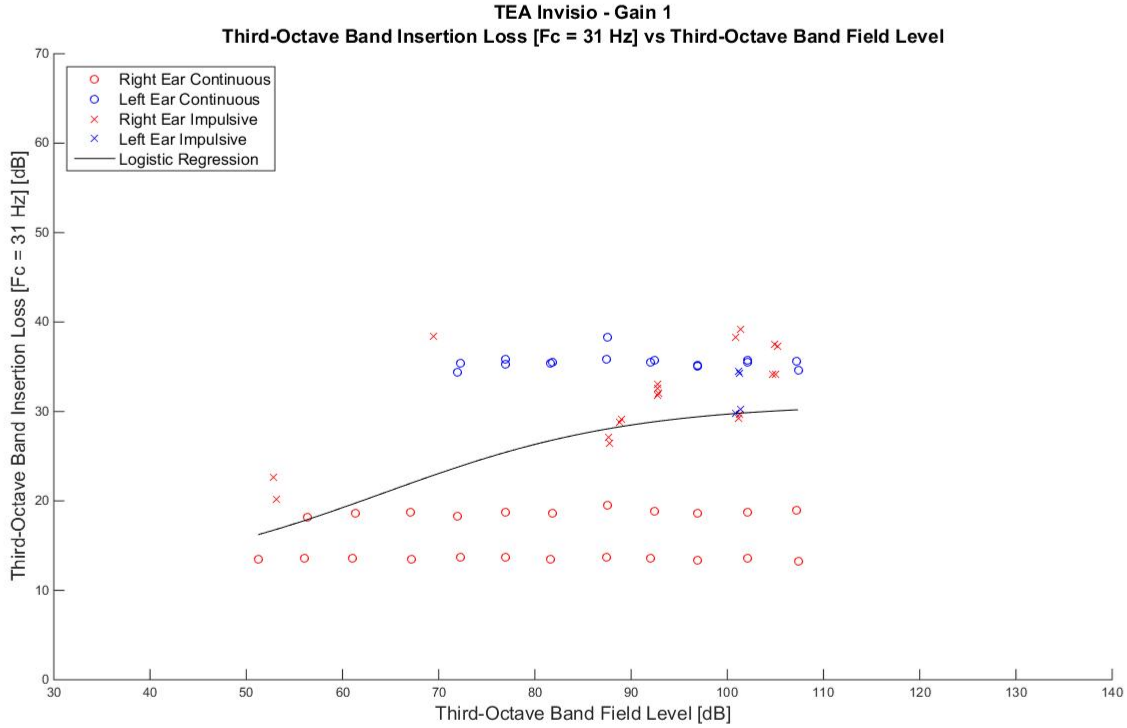

Figure A-282. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

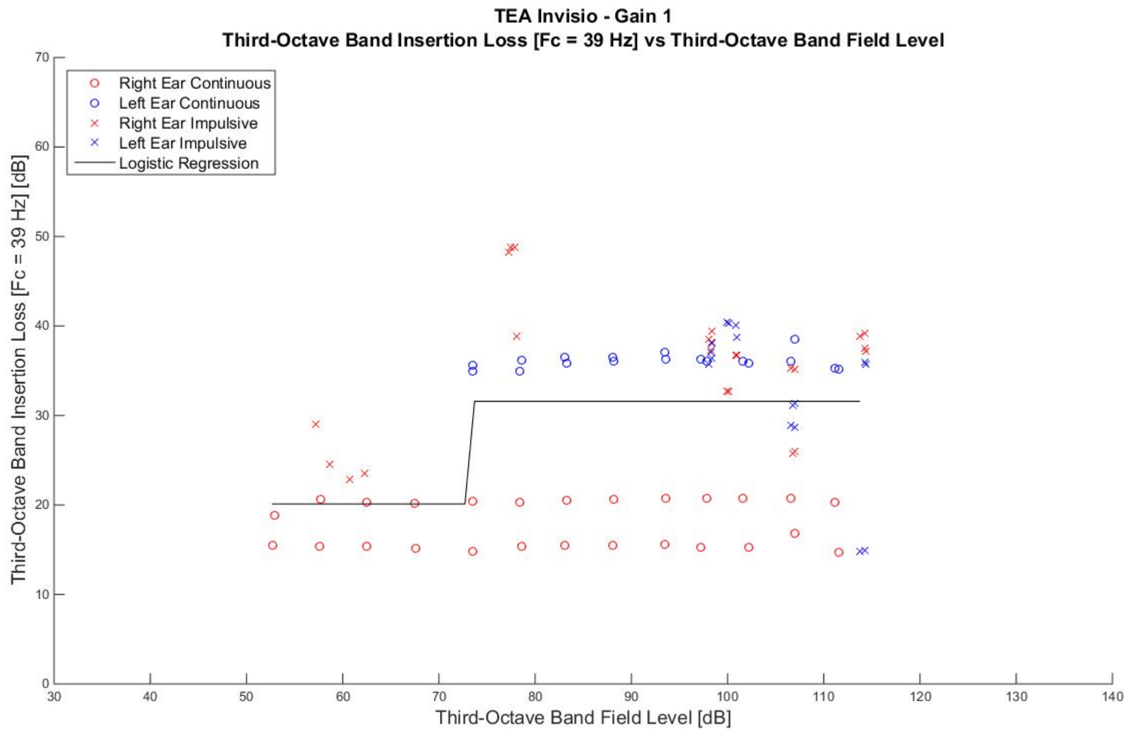

Figure A-283. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

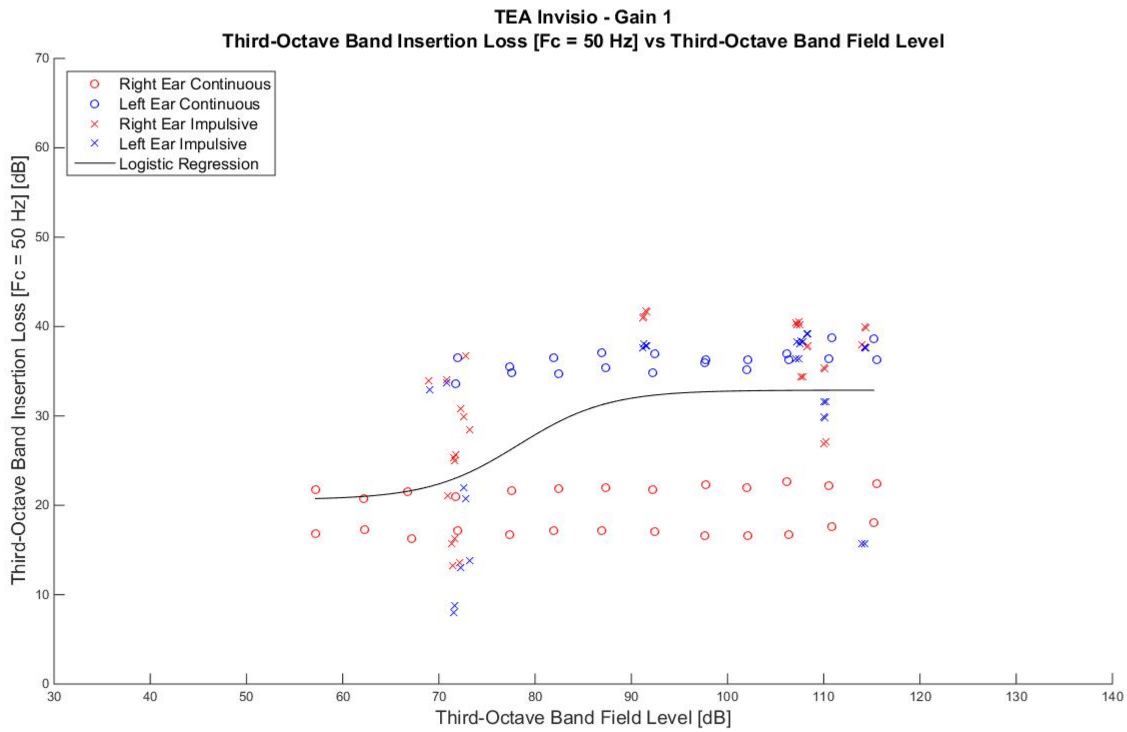

Figure A-284. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

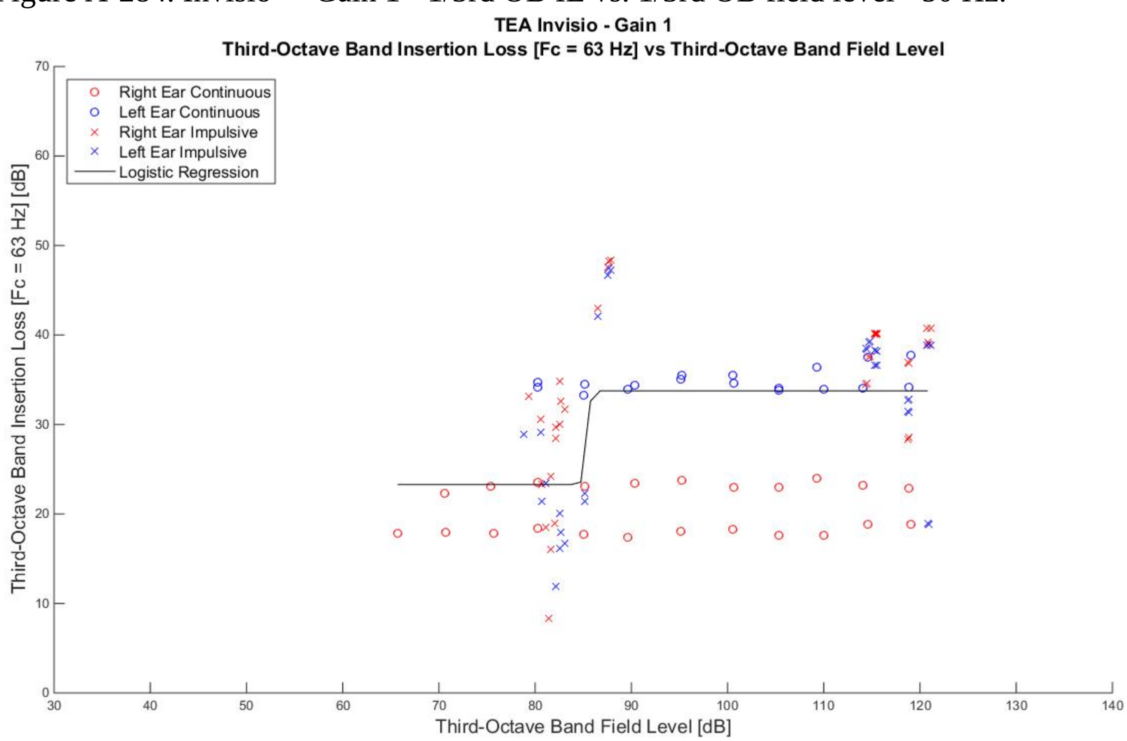

Figure A-285. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

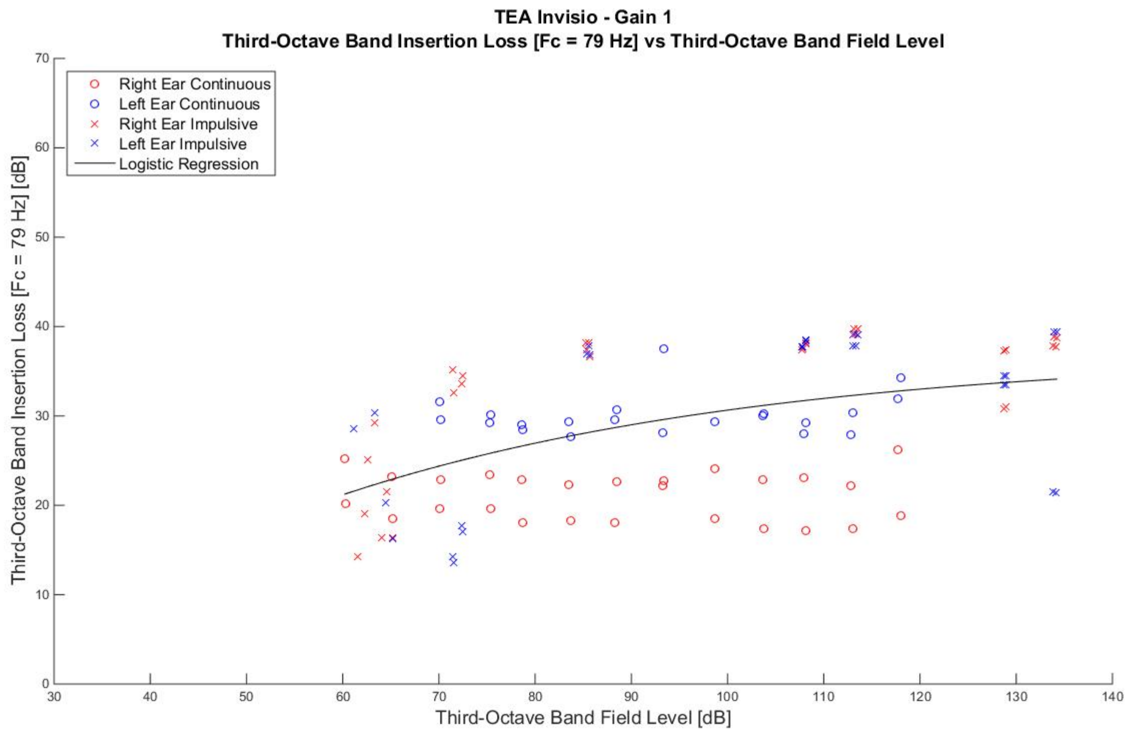

Figure A-286. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

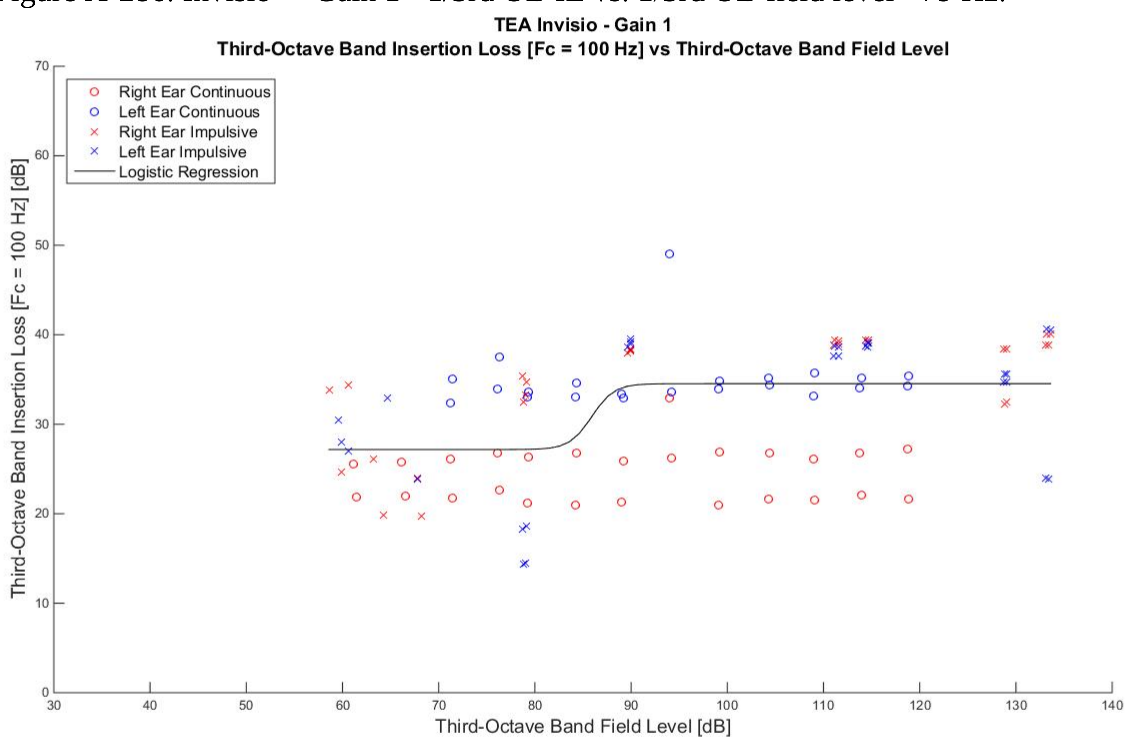

Figure A-287. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

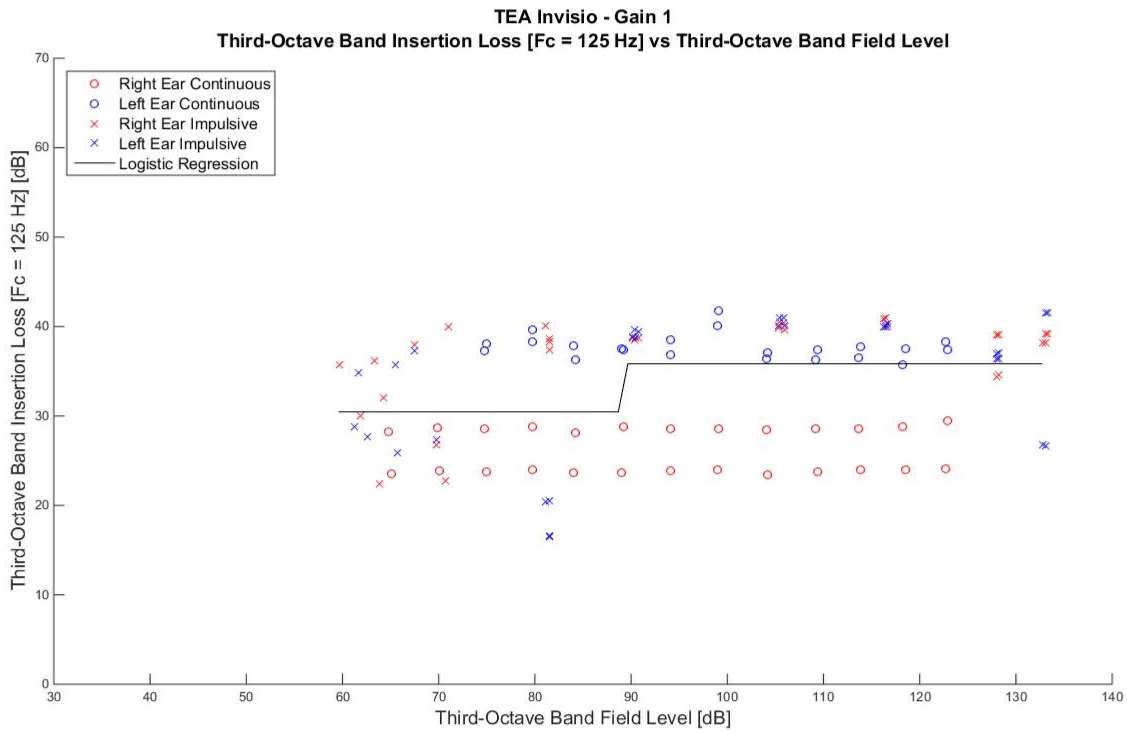

Figure A-288. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

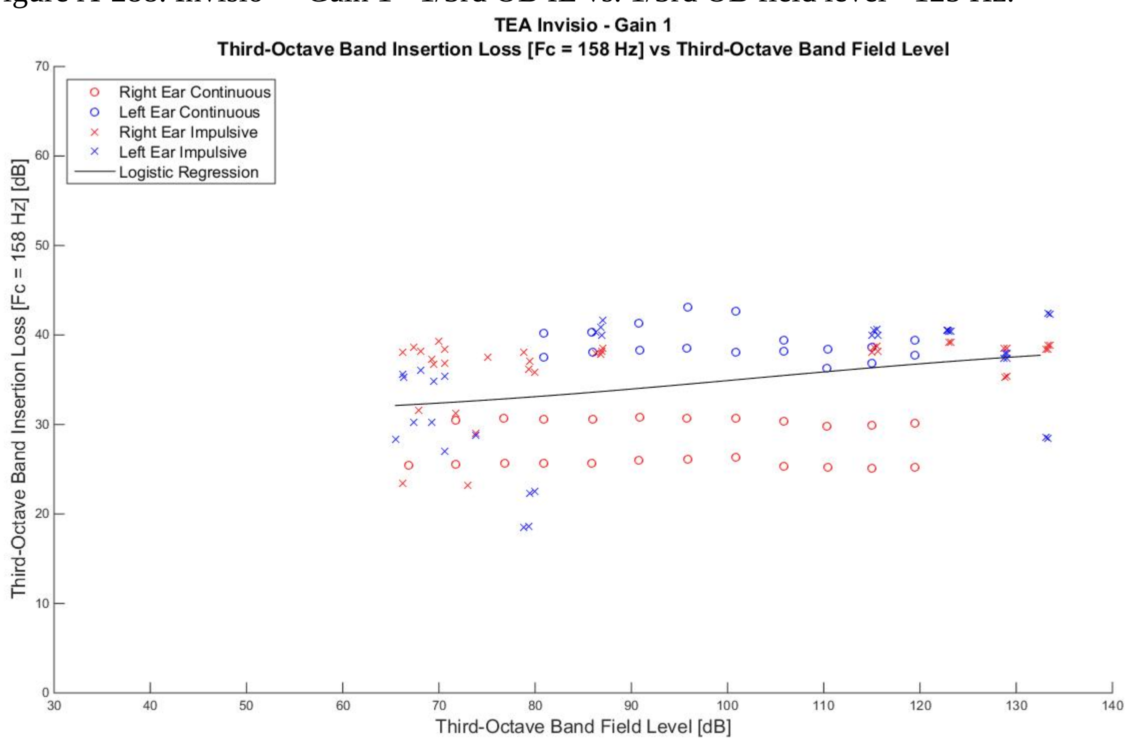

Figure A-289. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

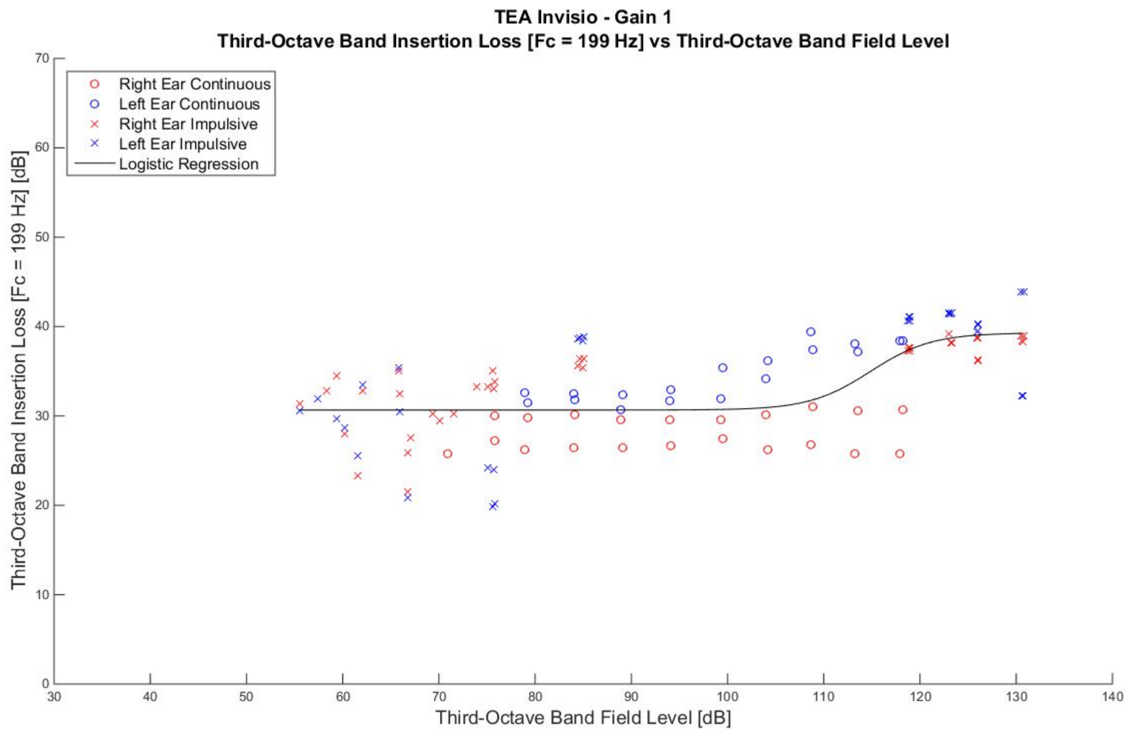

Figure A-290. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

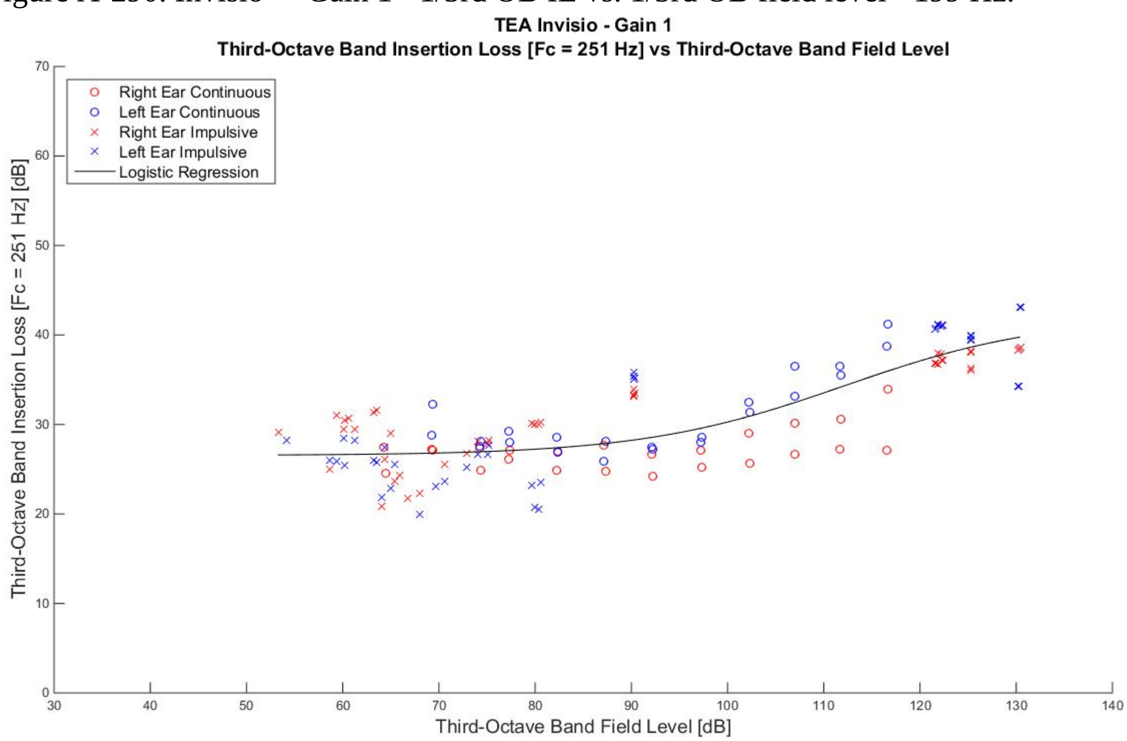

Figure A-291. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

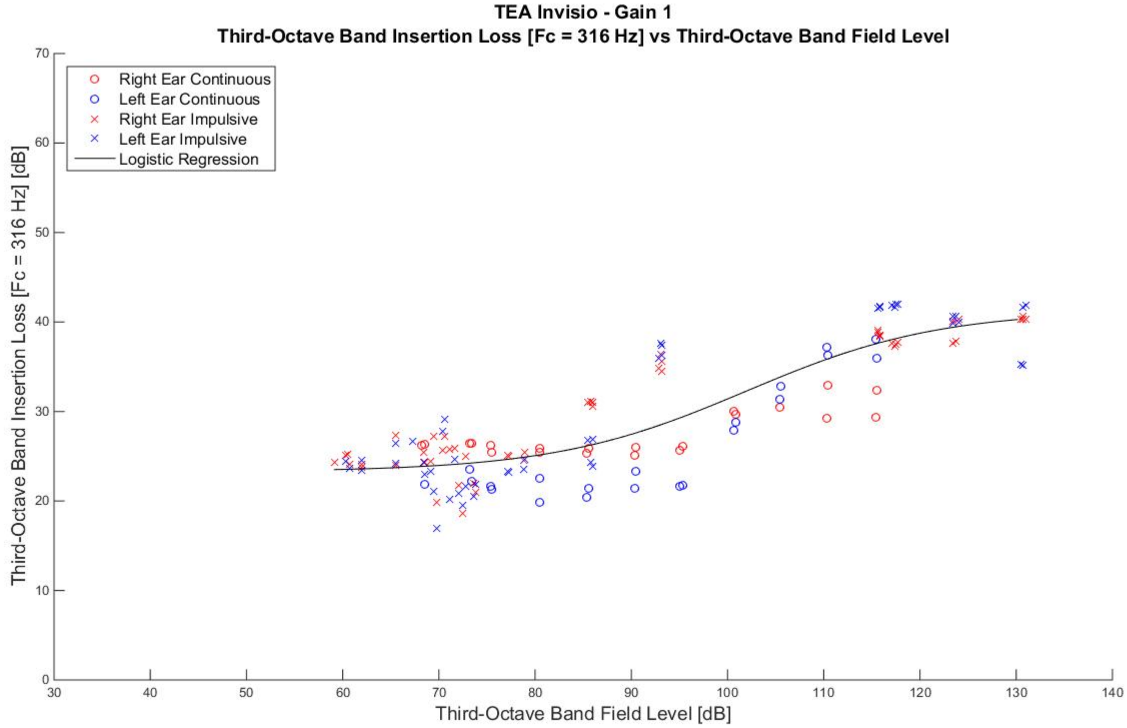

Figure A-292. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

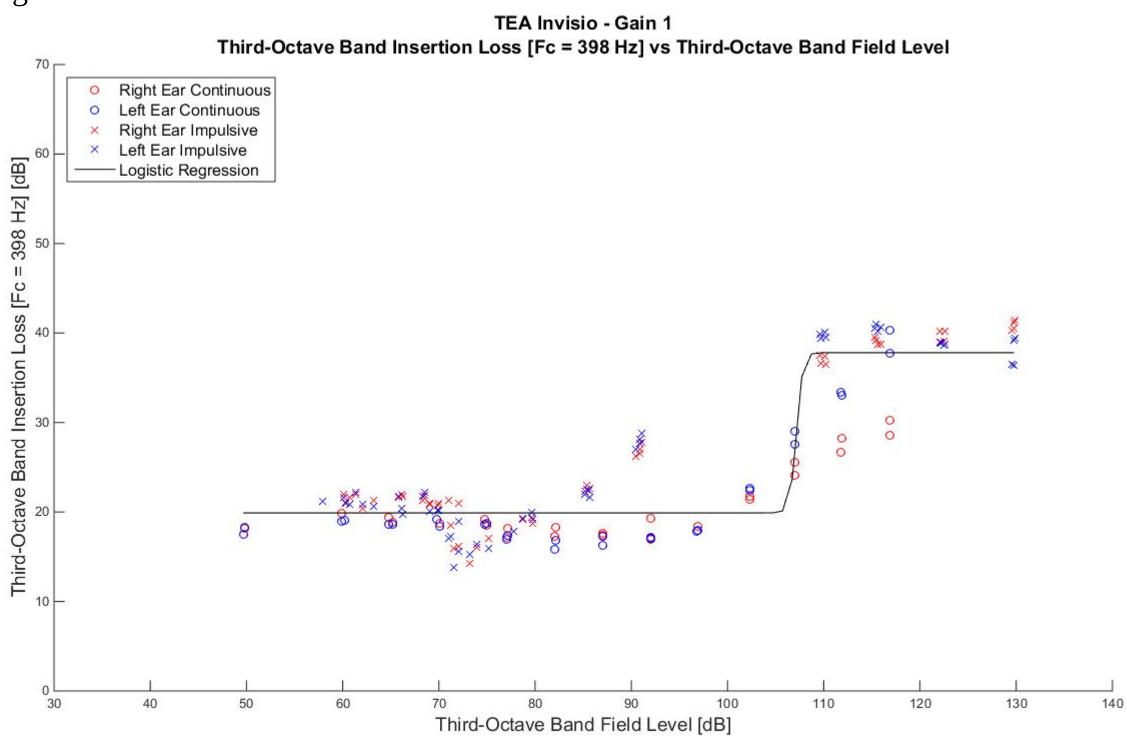

Figure A-293. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

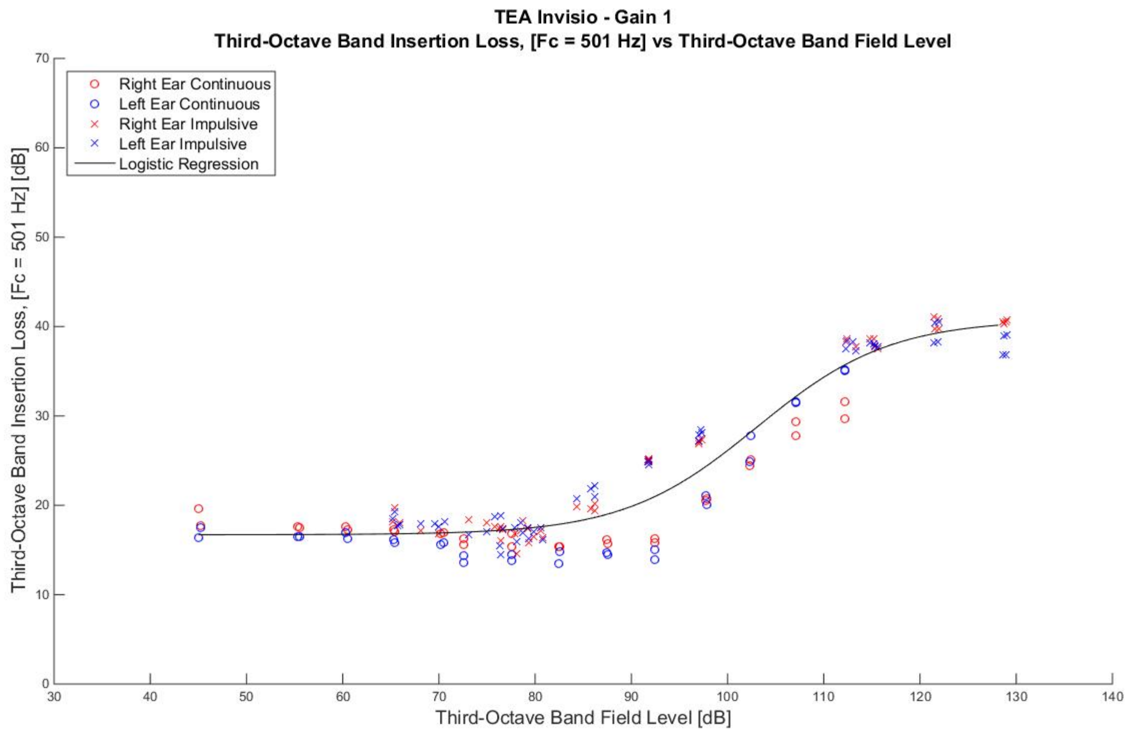

Figure A-294. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

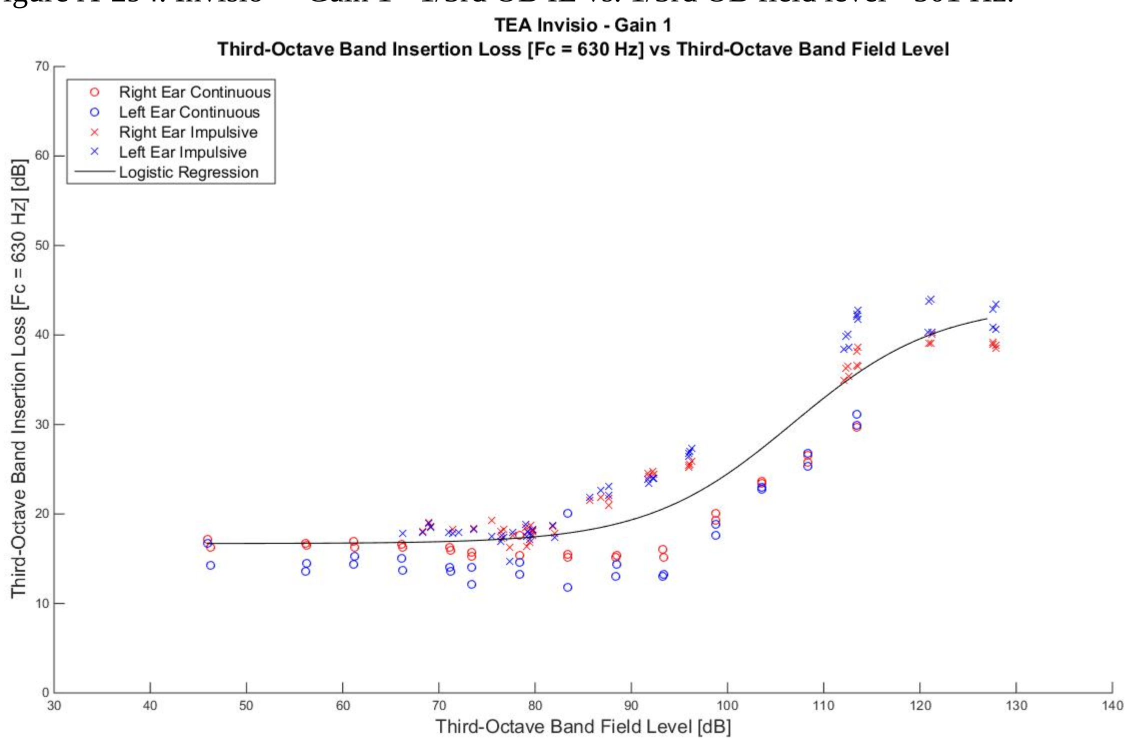

Figure A-295. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

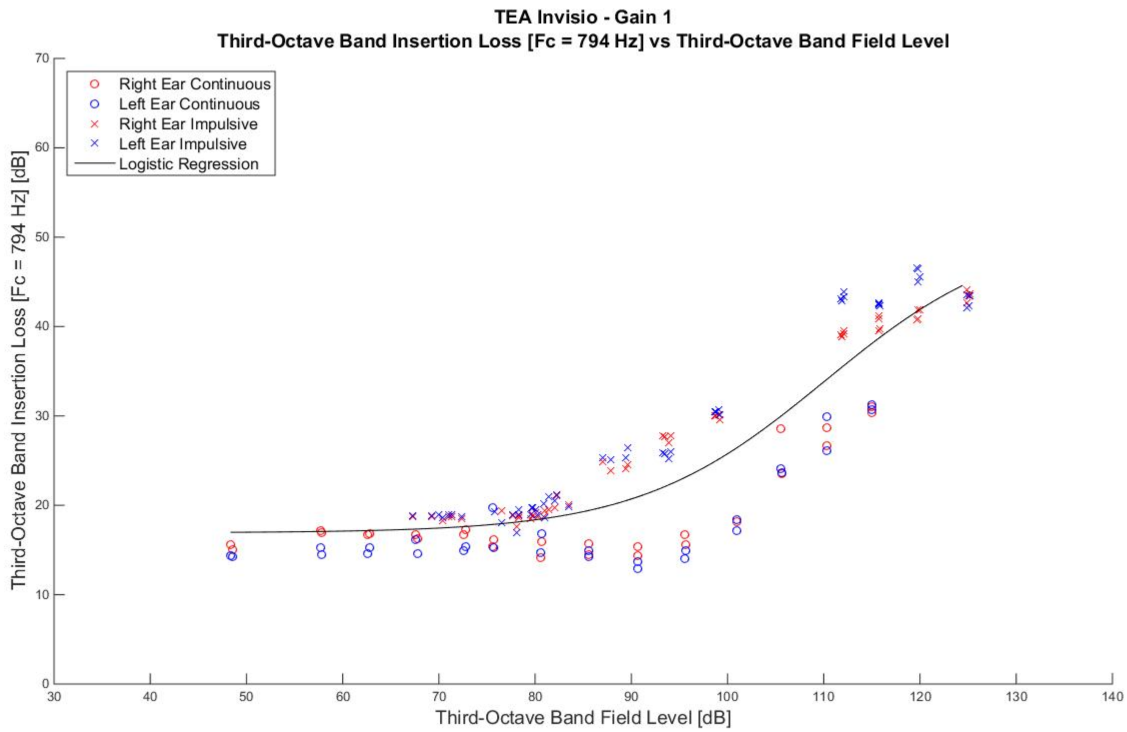

Figure A-296. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

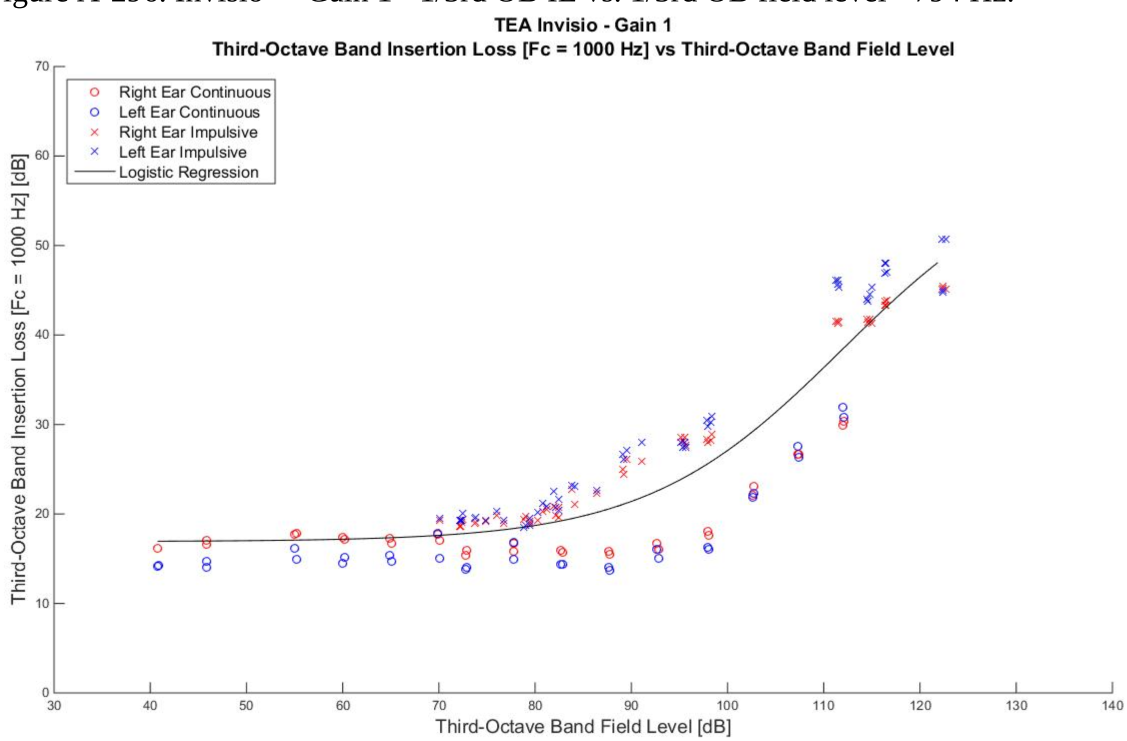

Figure A-297. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

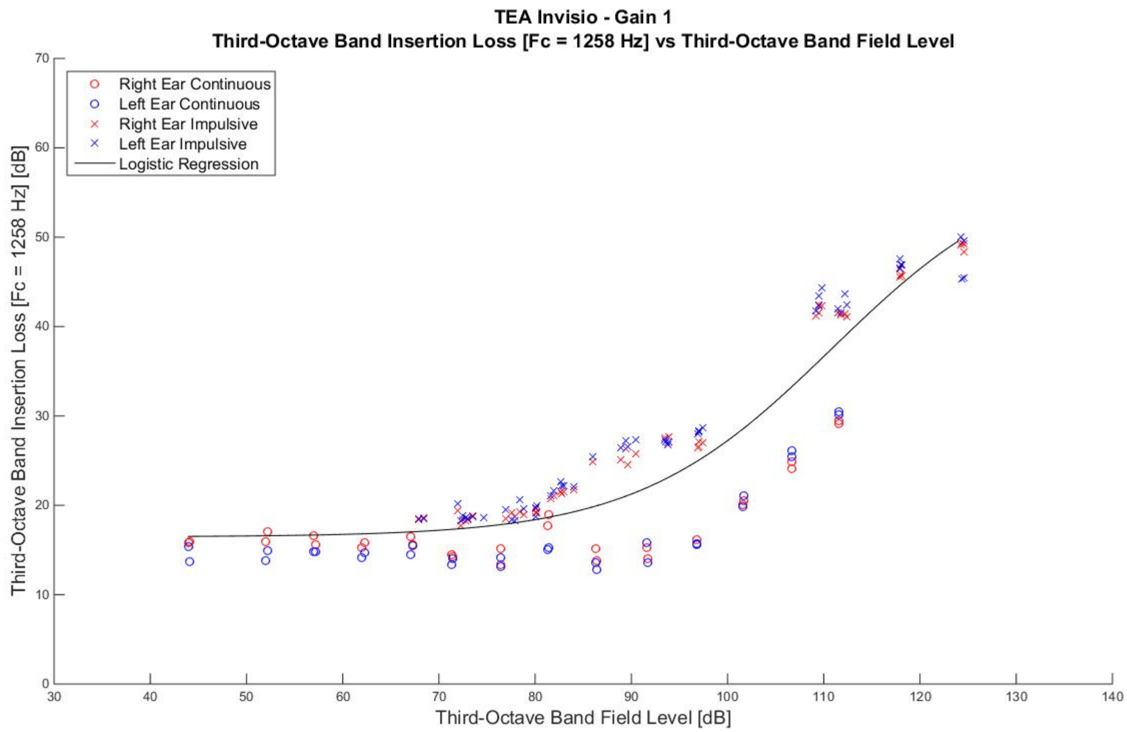

Figure A-298. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

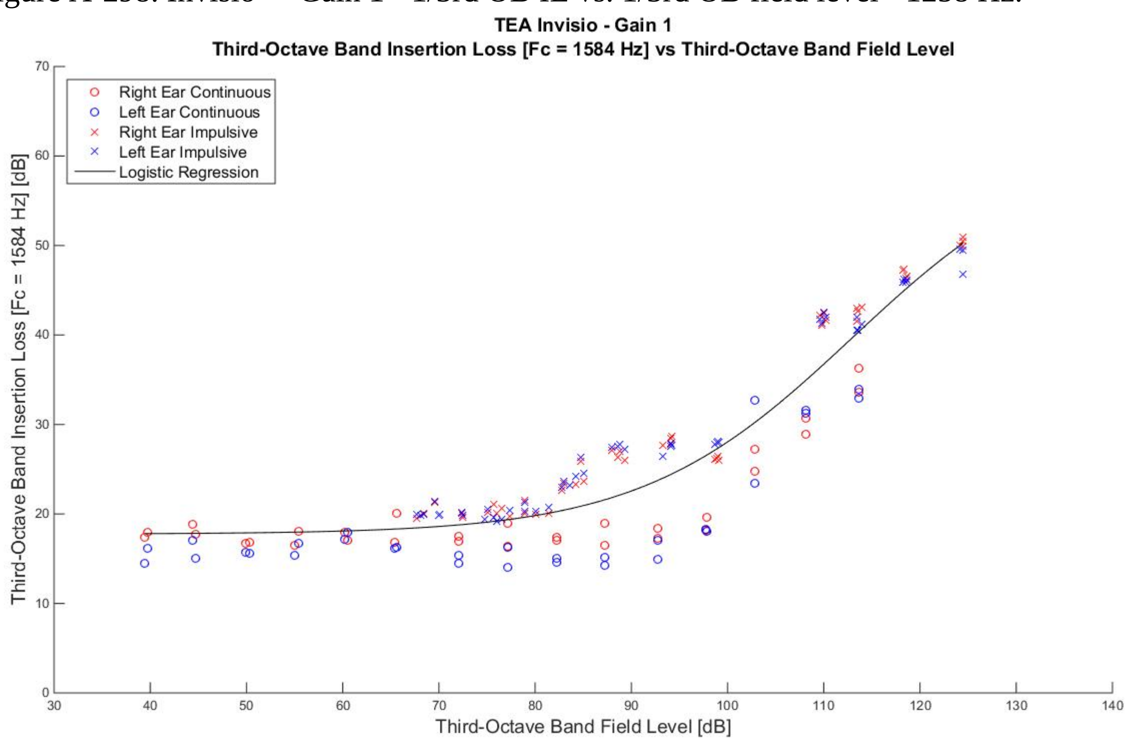

Figure A-299. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

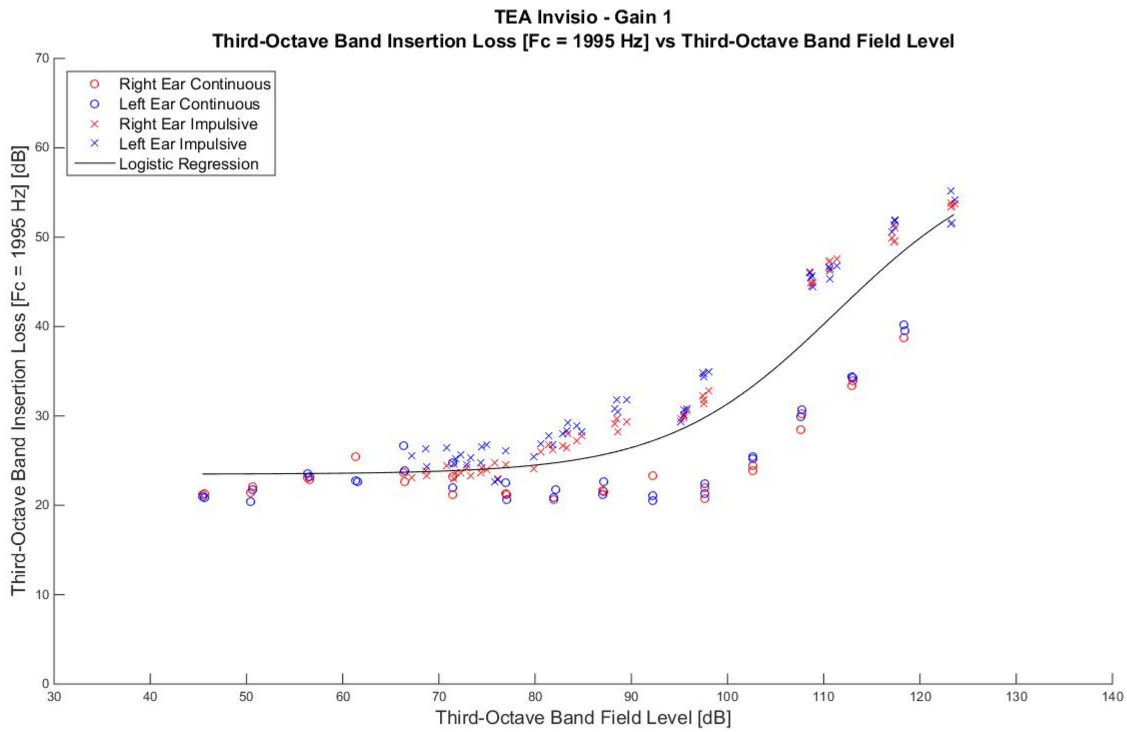

Figure A-300. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

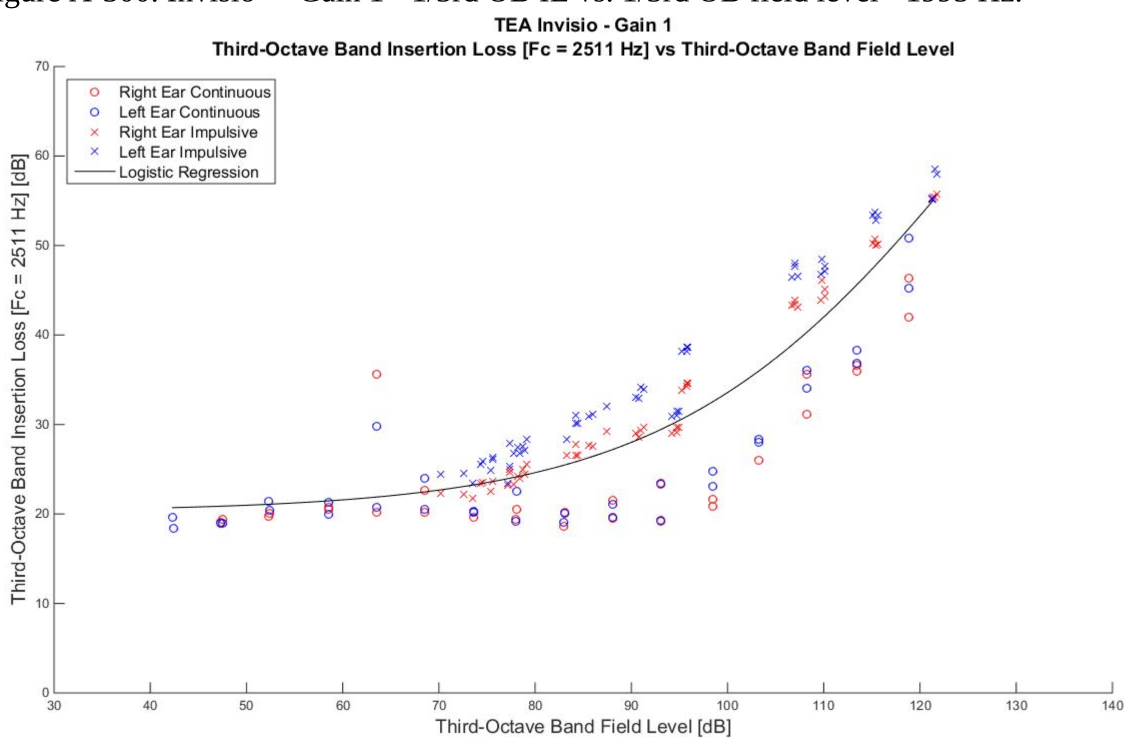

Figure A-301. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

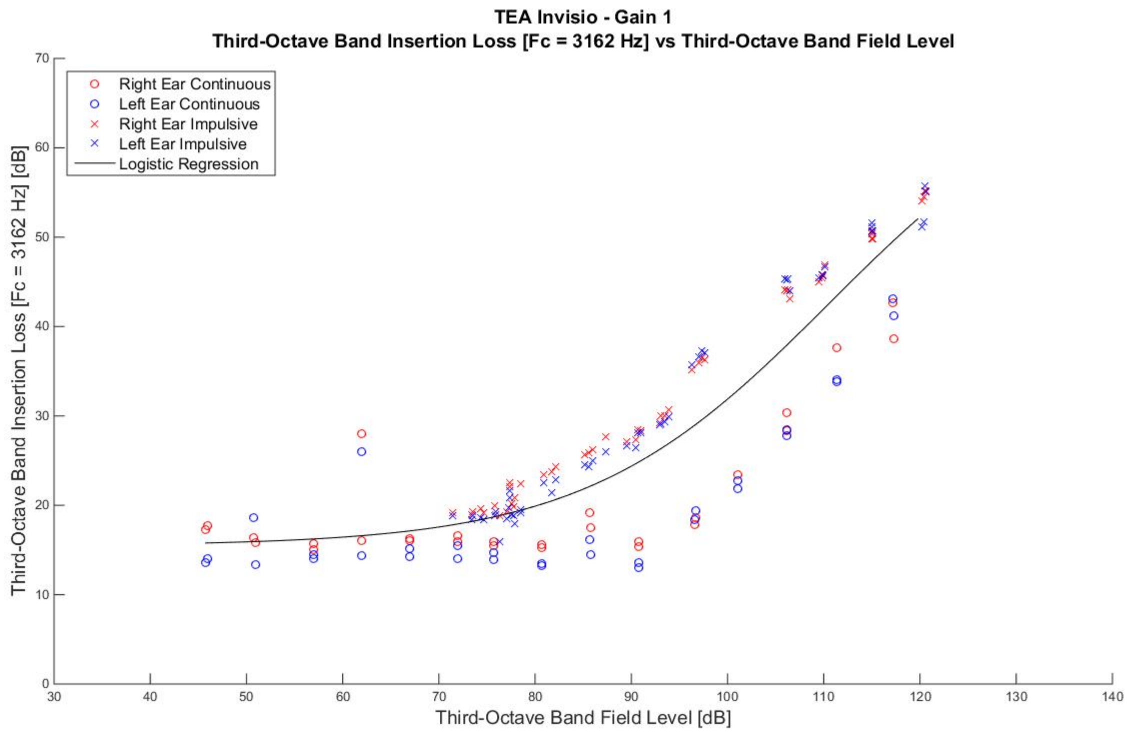

Figure A-302. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

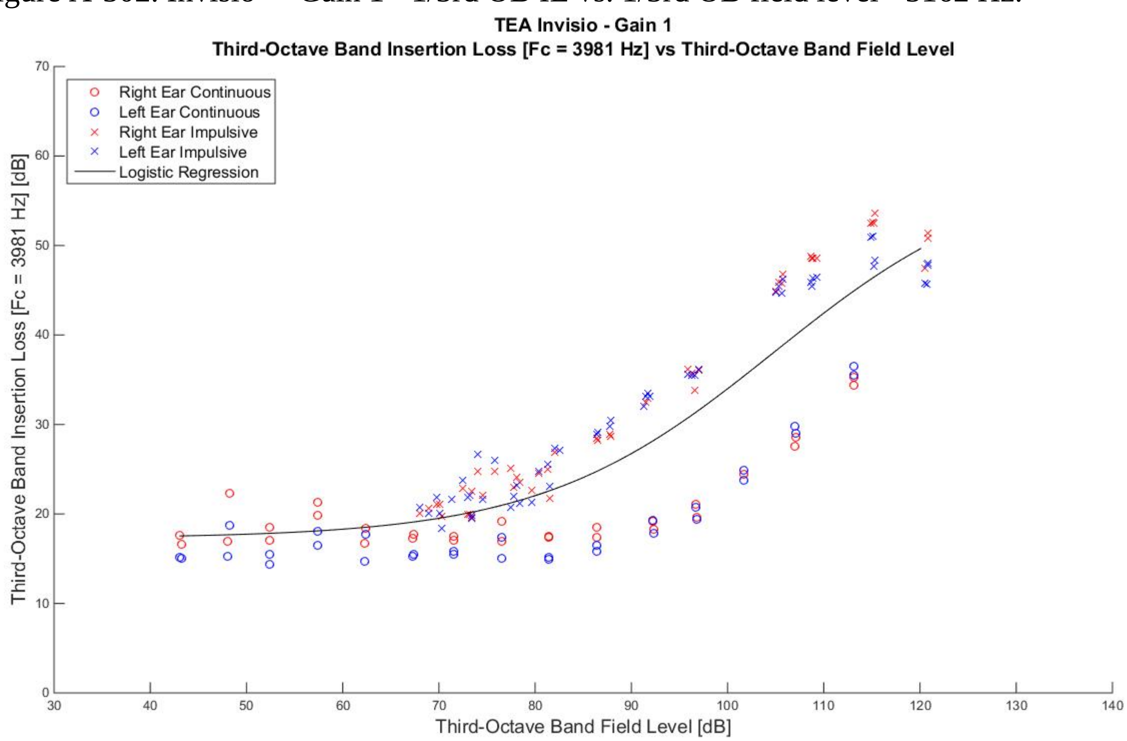

Figure A-303. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

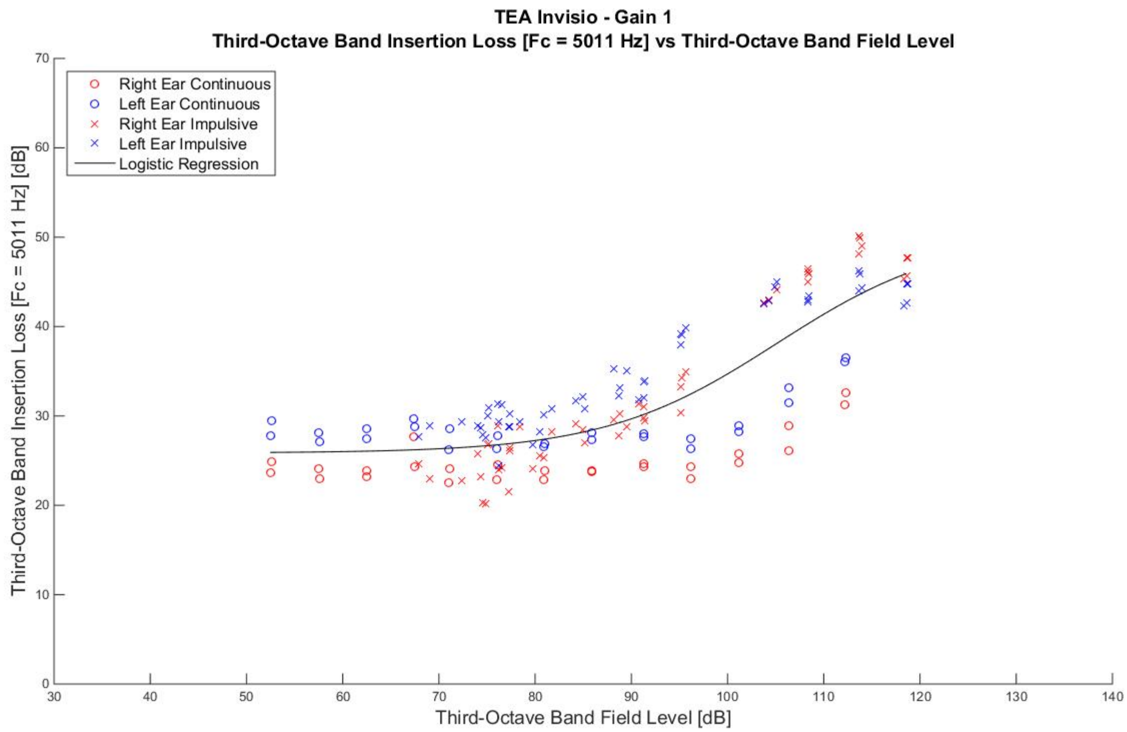

Figure A-304. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

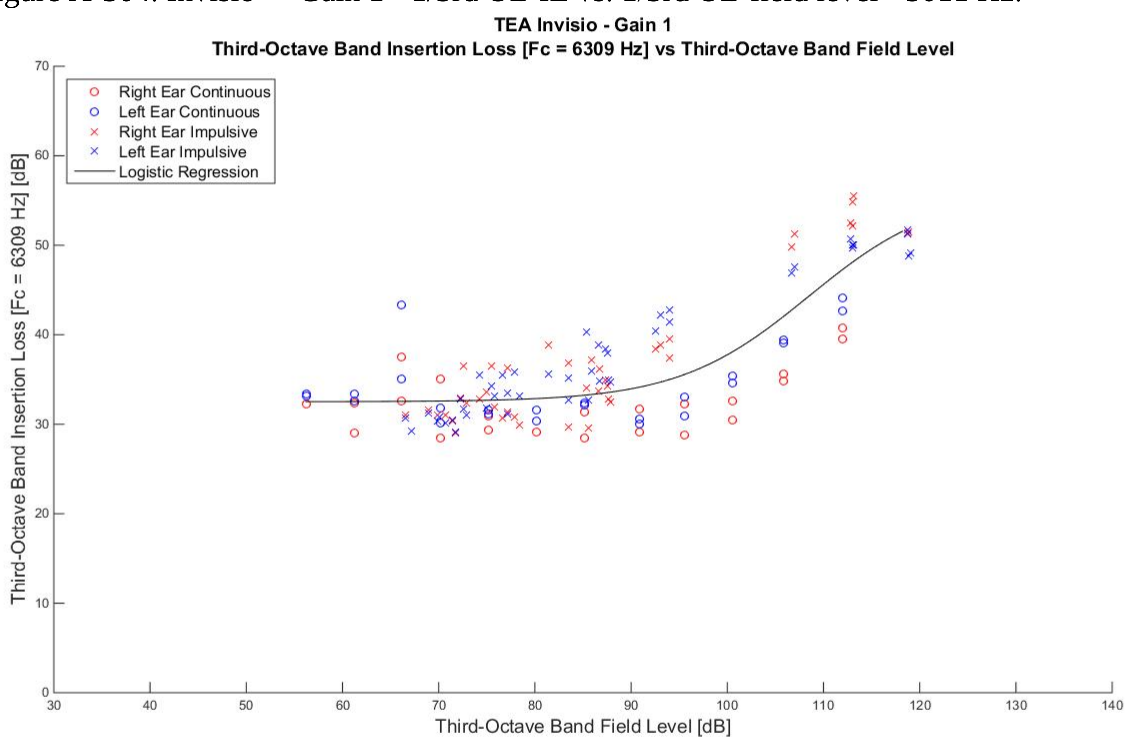

Figure A-305. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

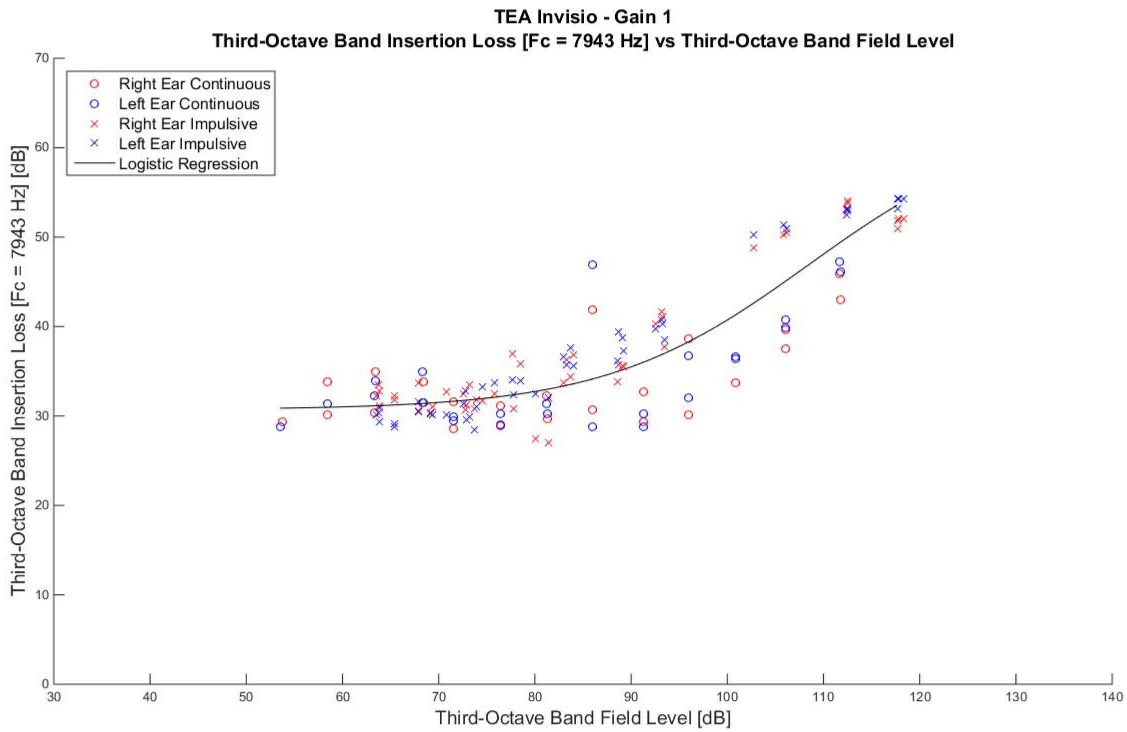

Figure A-306. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

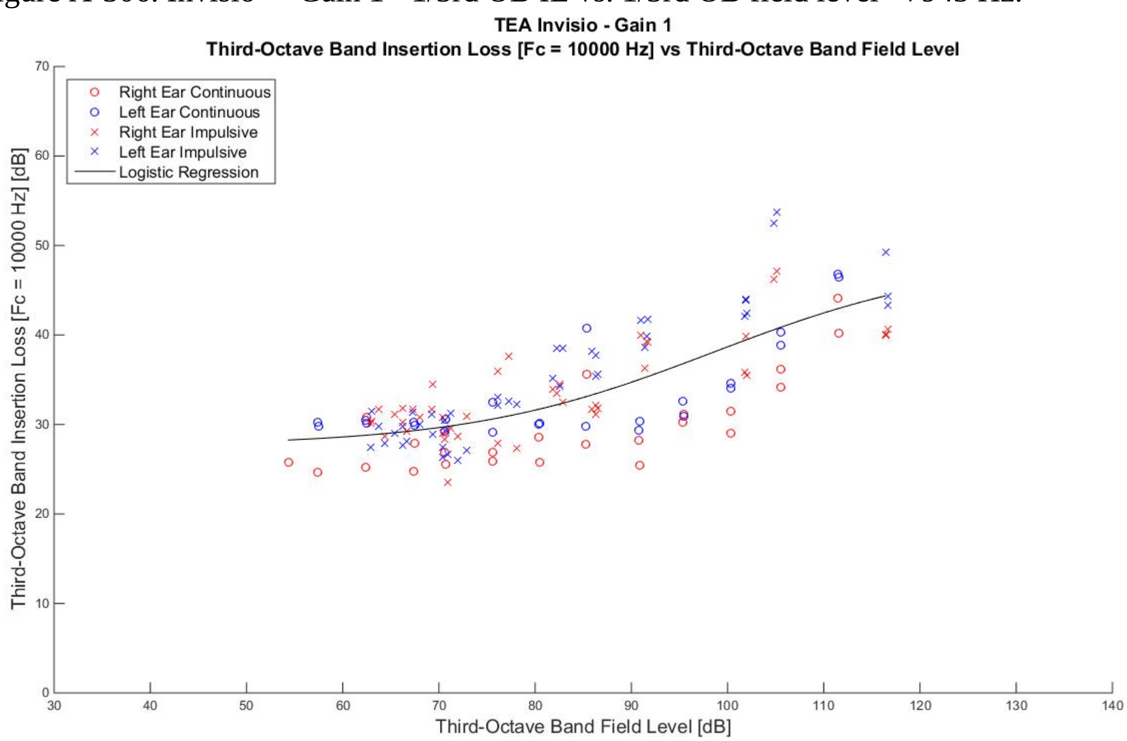

Figure A-307. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

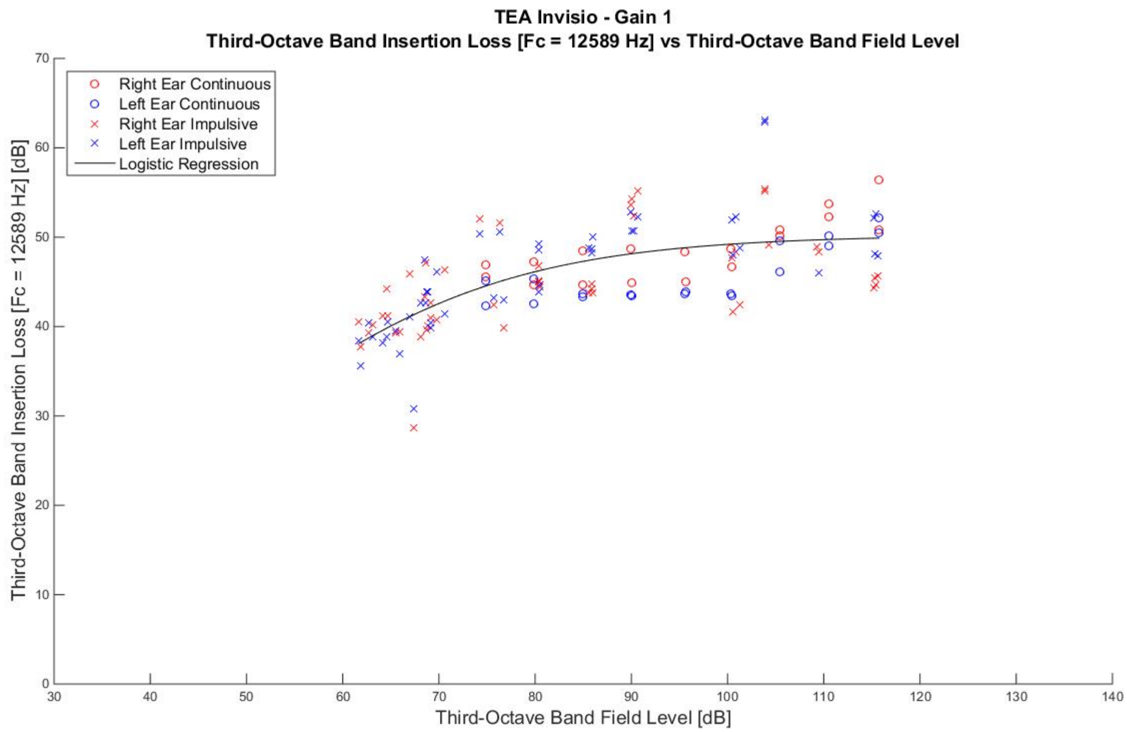

Figure A-308. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

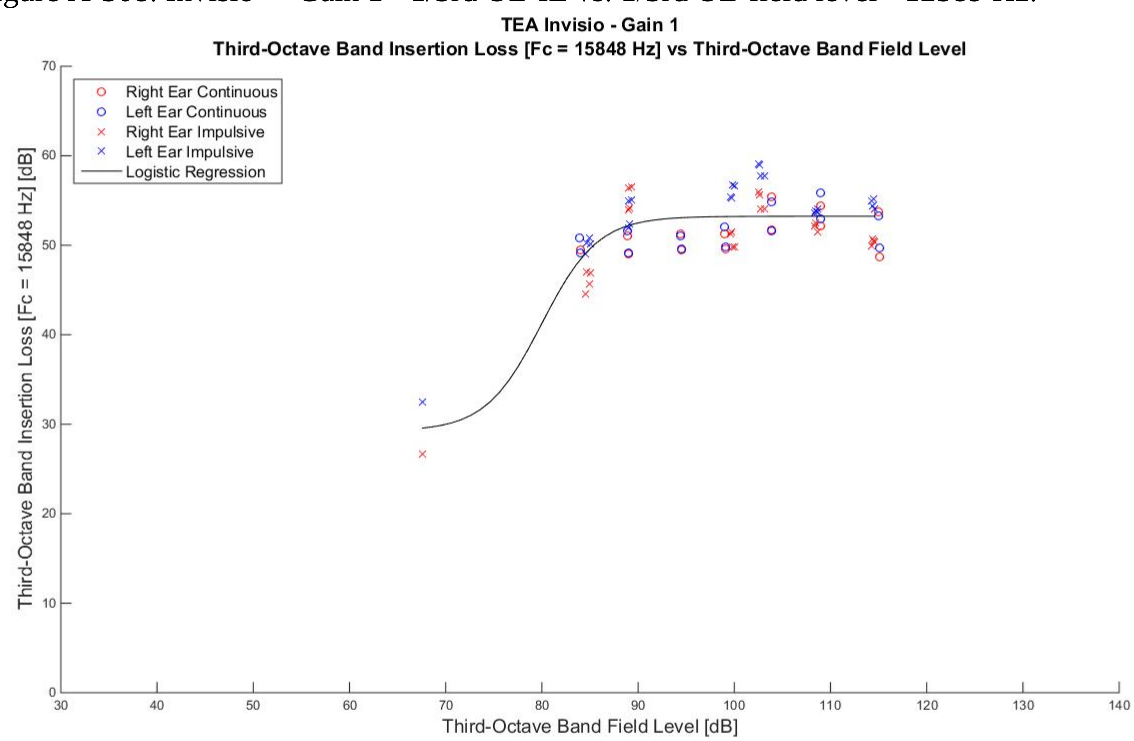

Figure A-309. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

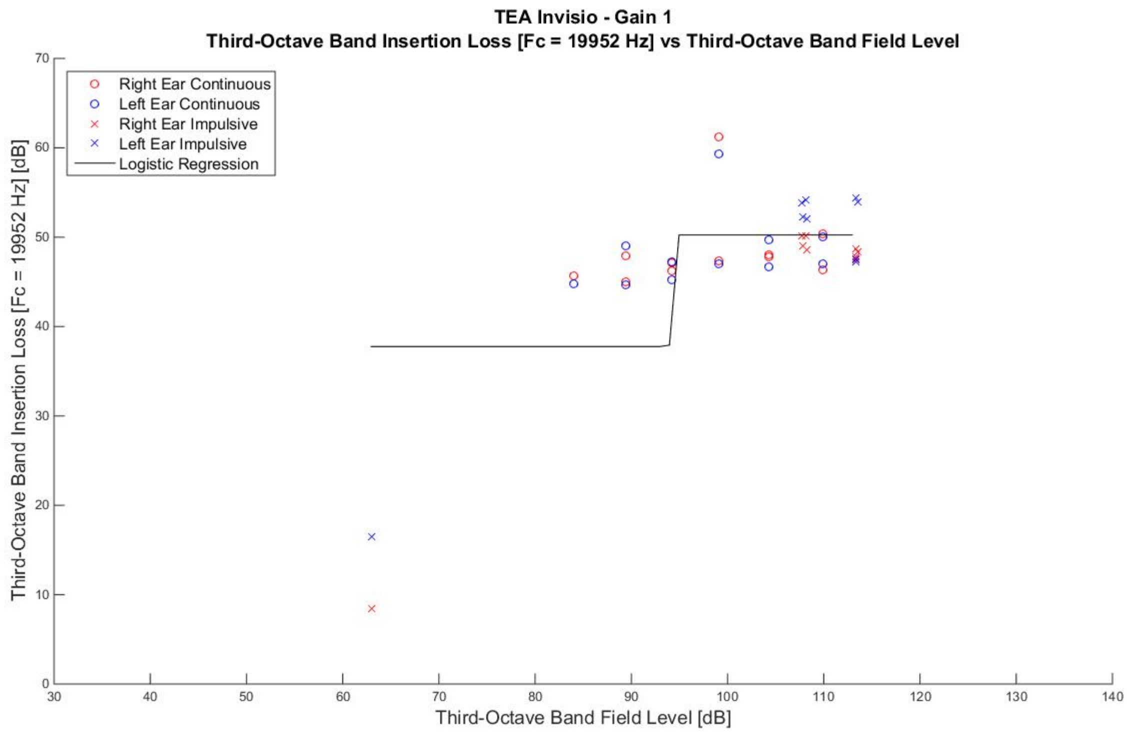

Figure A-310. Invisio® - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

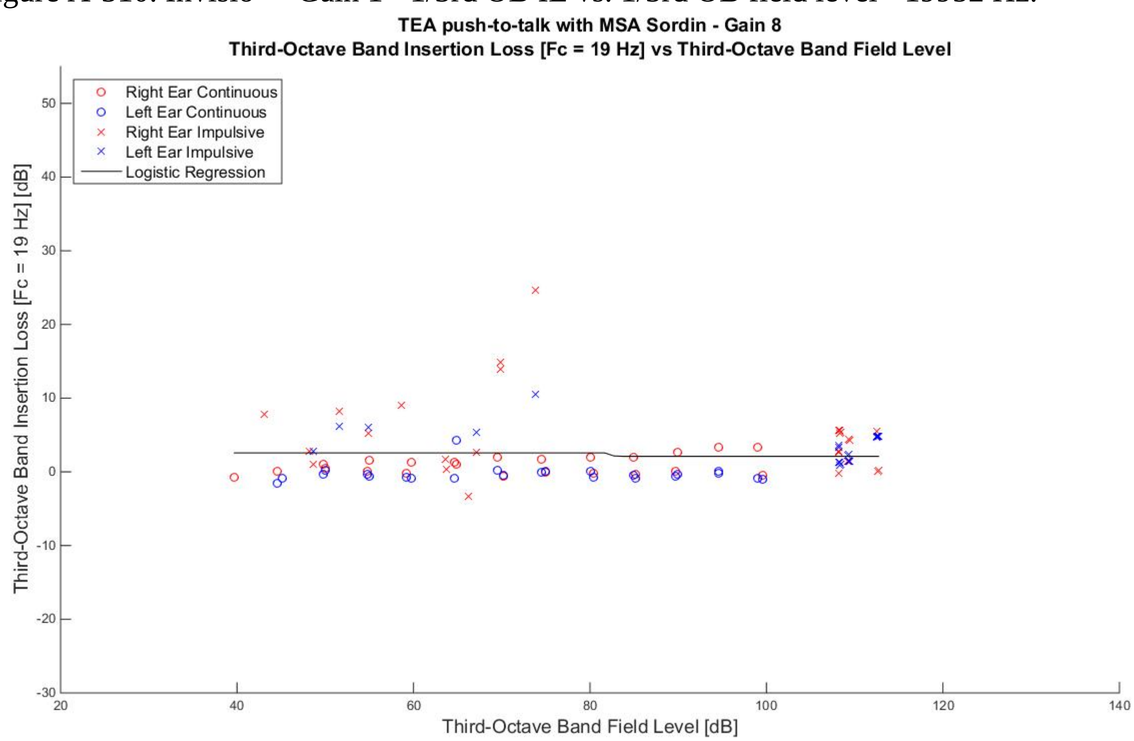

Figure A-311. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

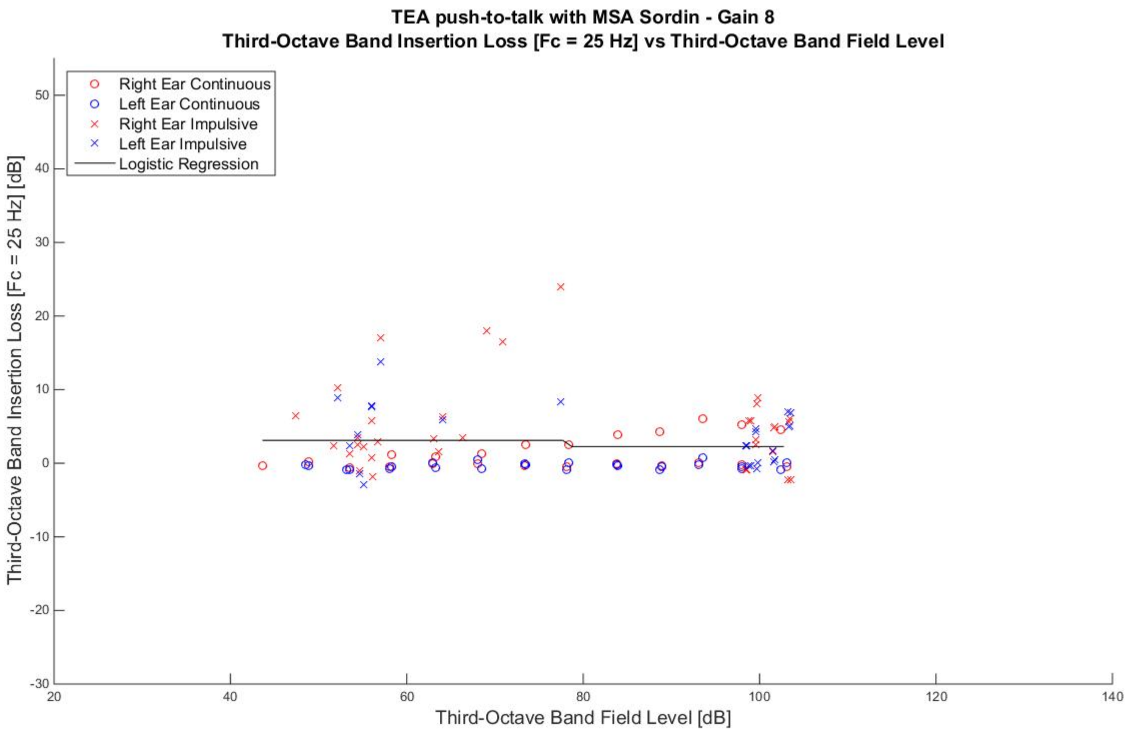

Figure A-312. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

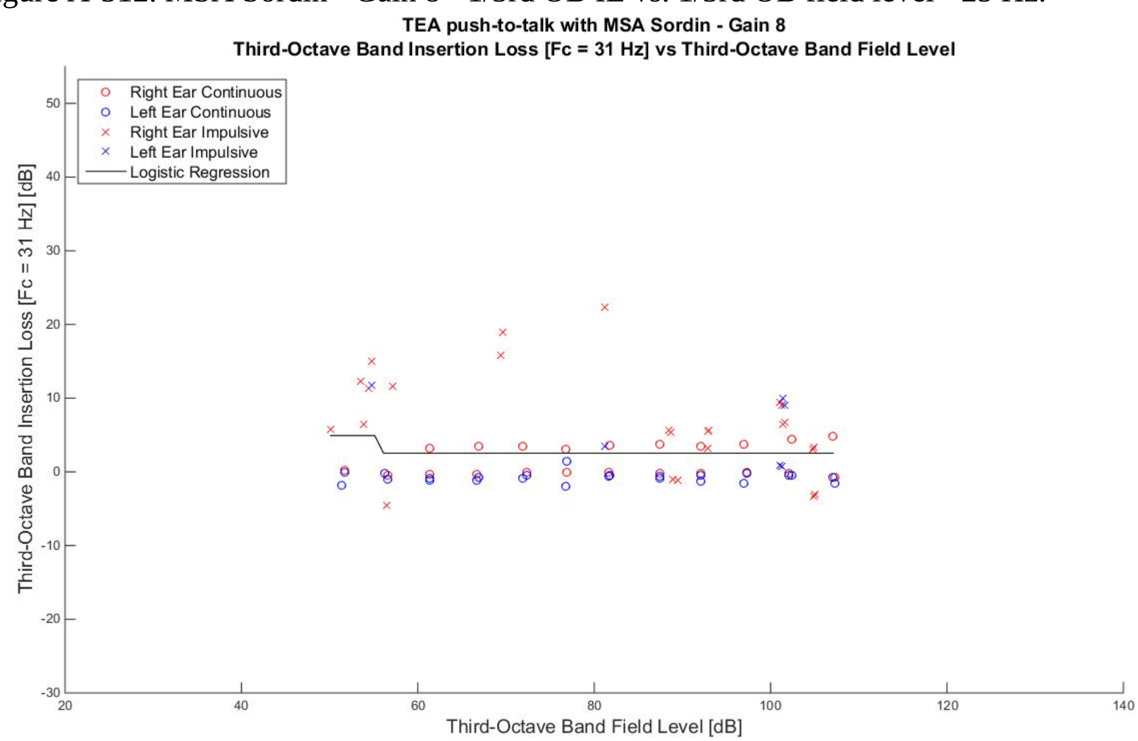

Figure A-313. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

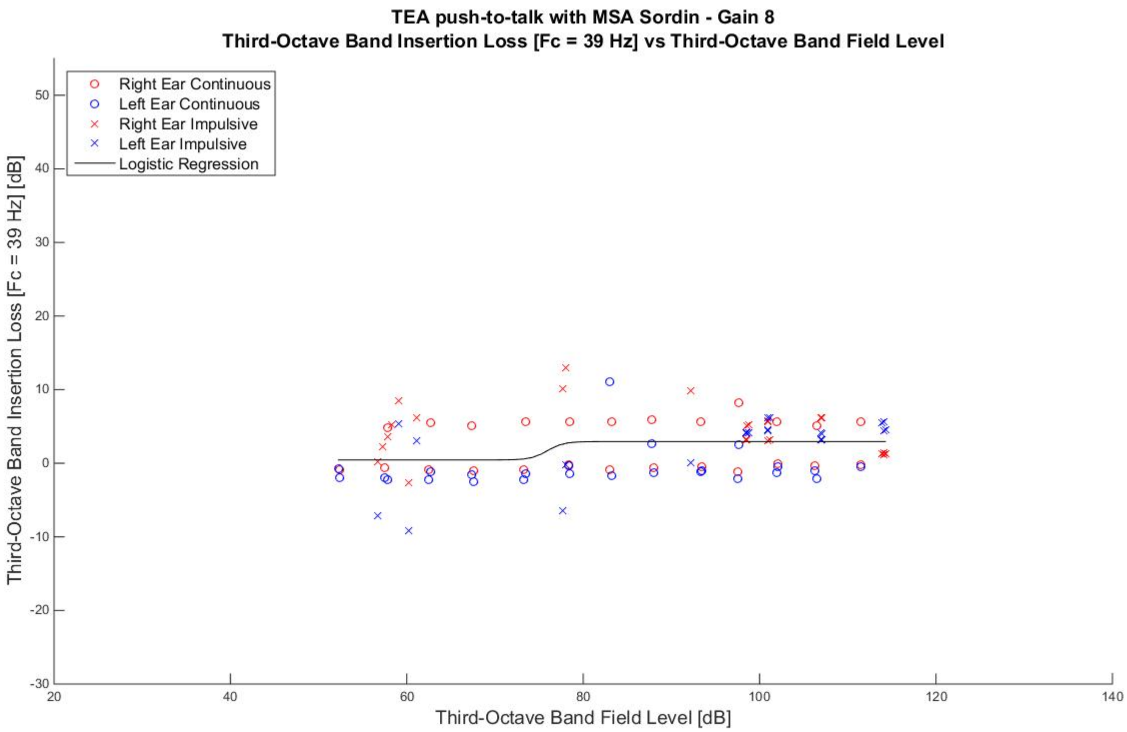

Figure A-314. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

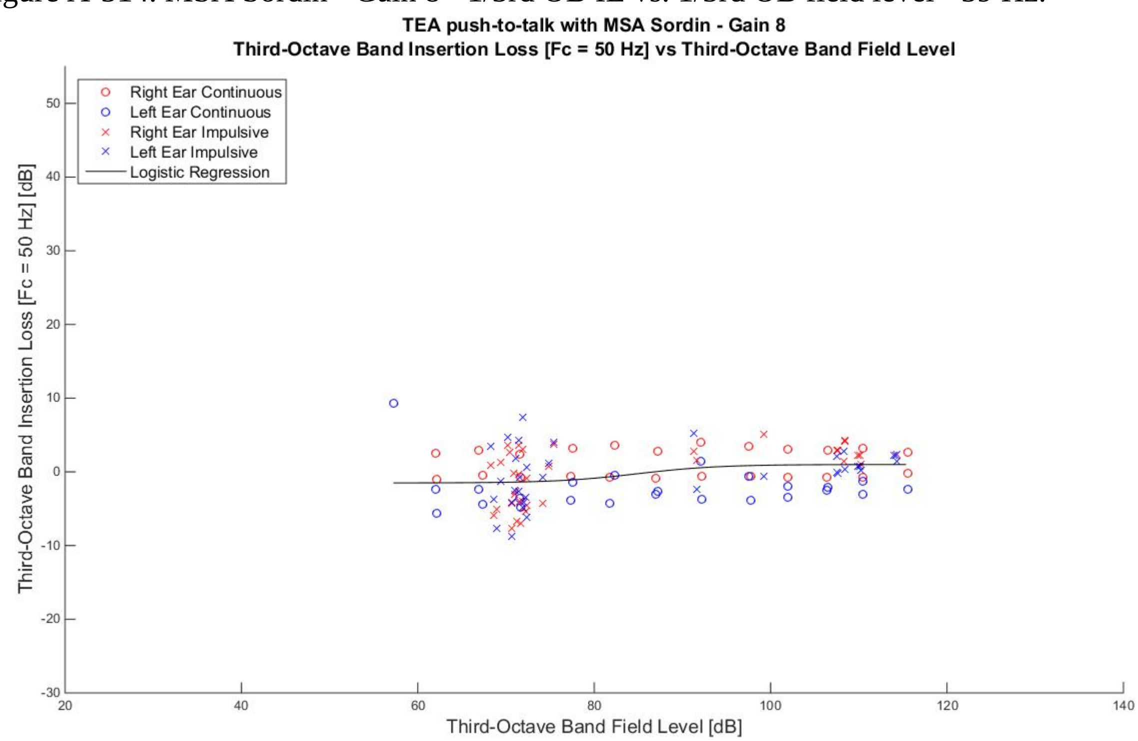

Figure A-315. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

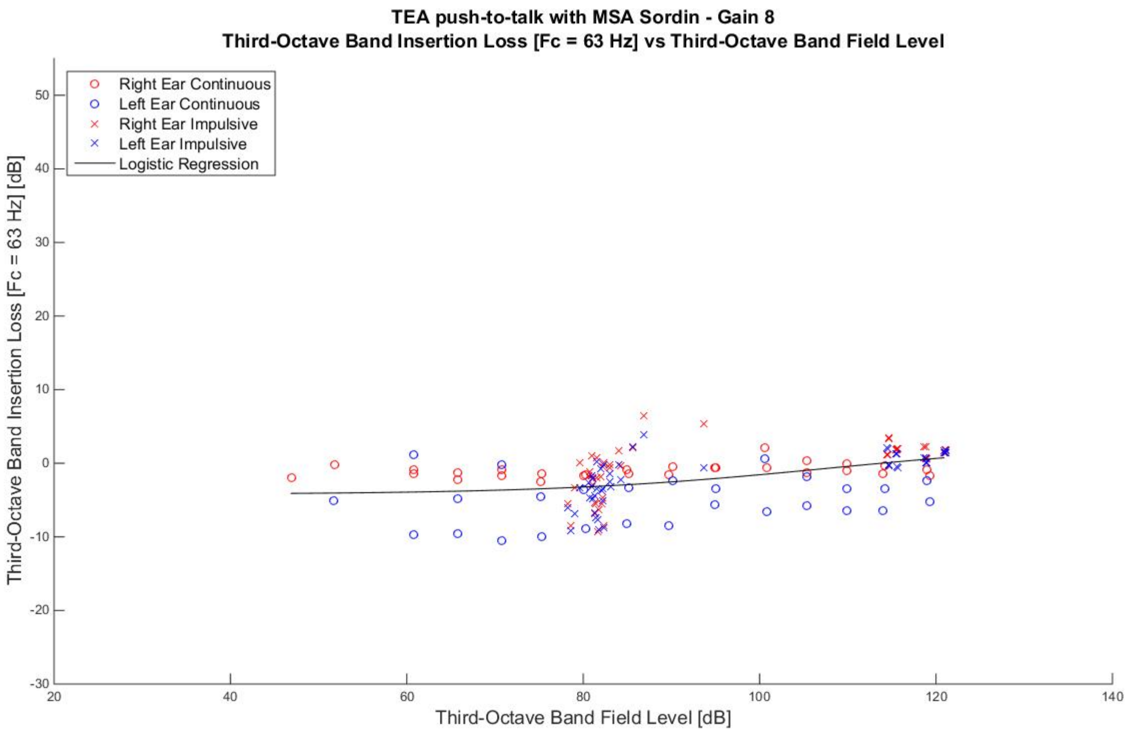

Figure A-316. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

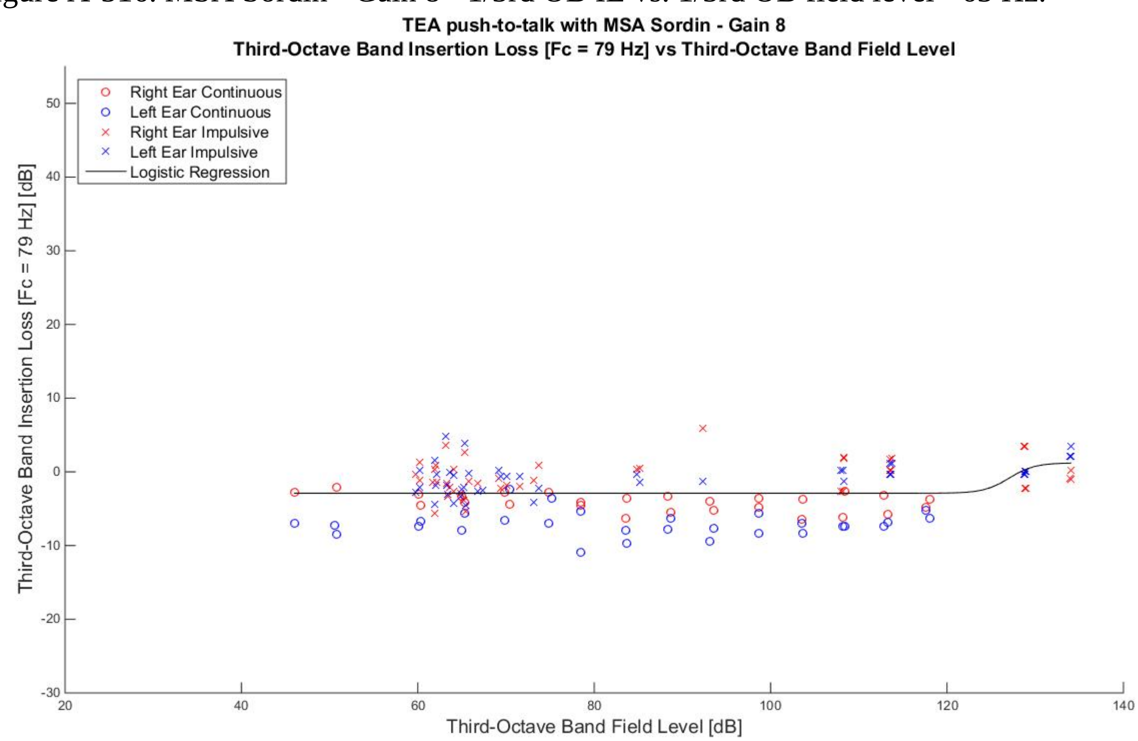

Figure A-317. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

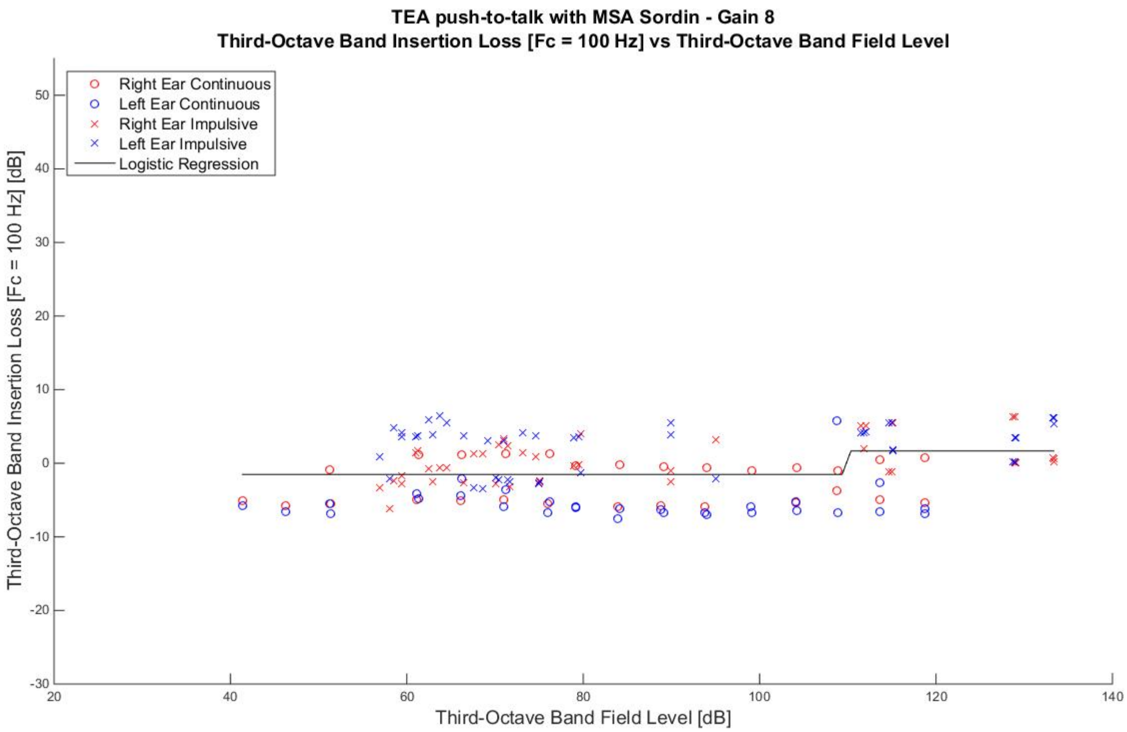

Figure A-318. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

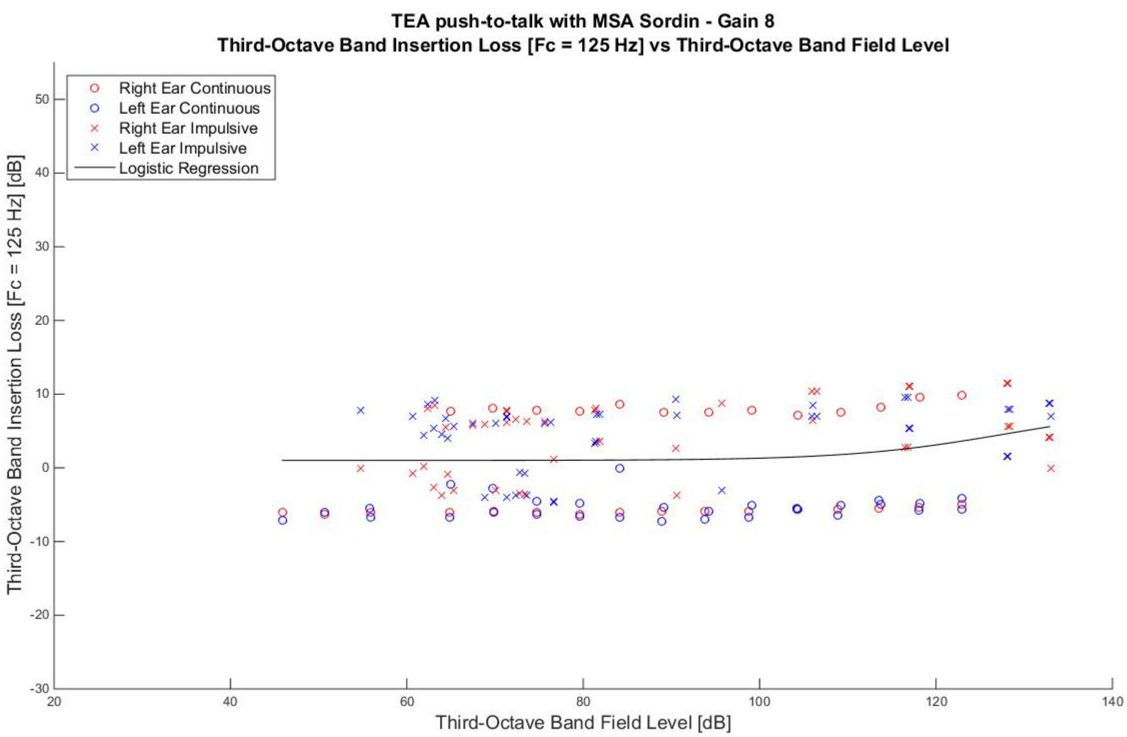

Figure A-319. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

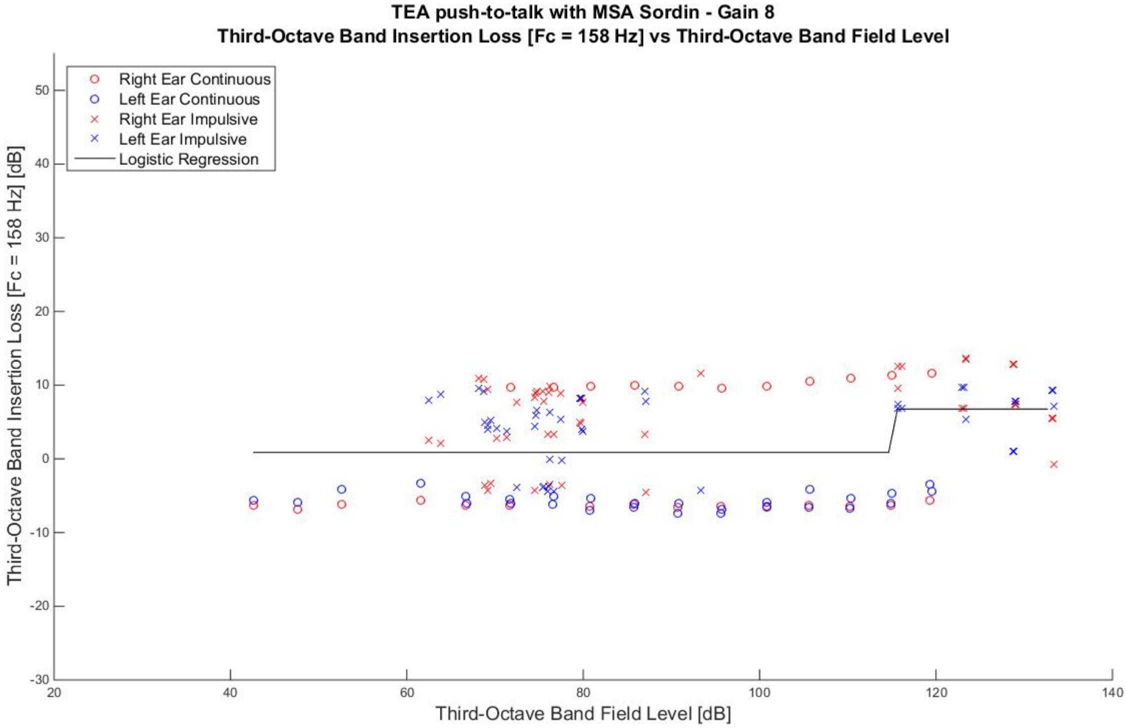

Figure A-320. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

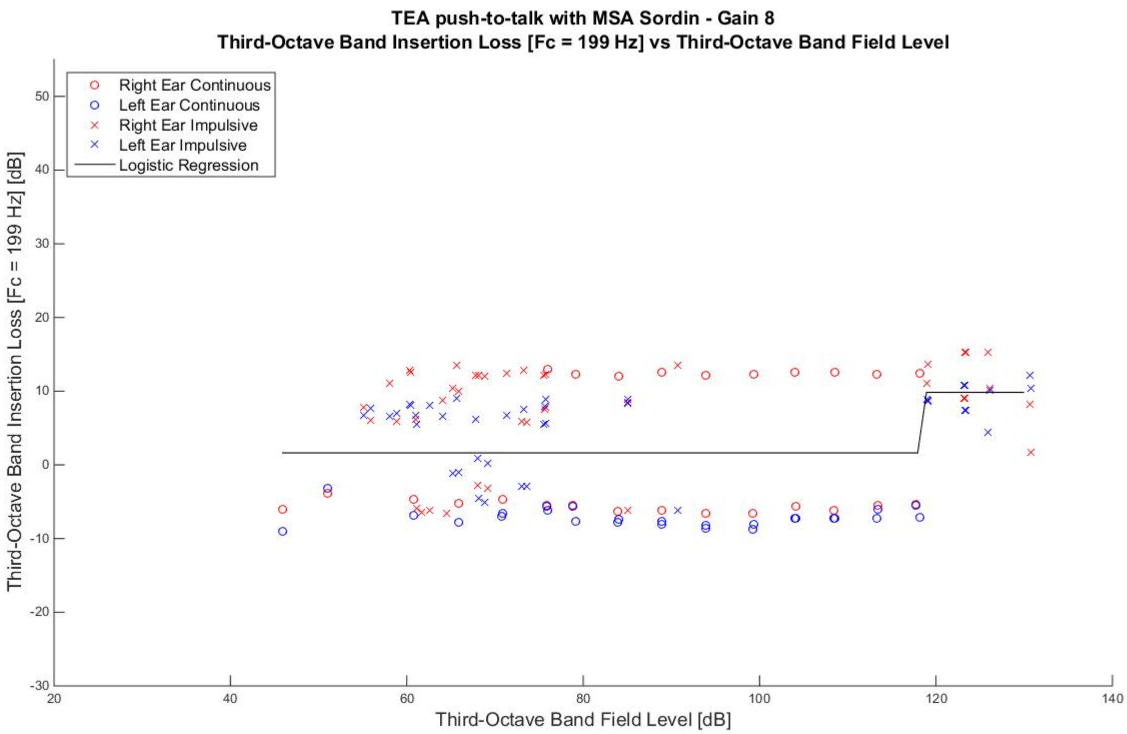

Figure A-321. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

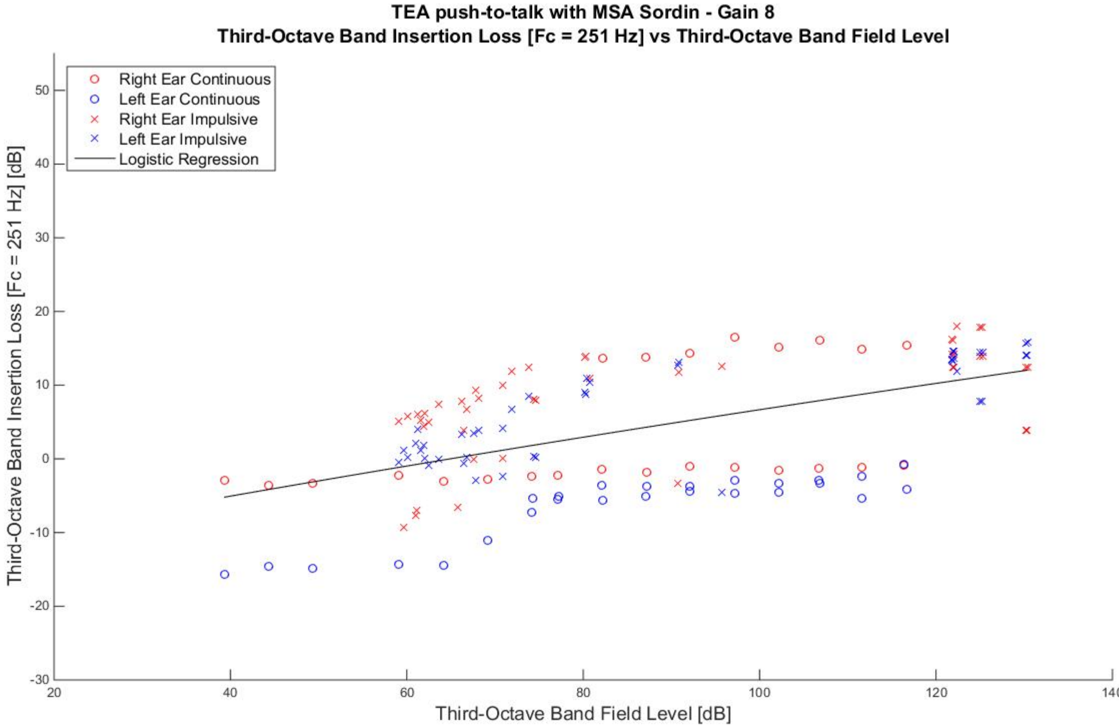

Figure A-322. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

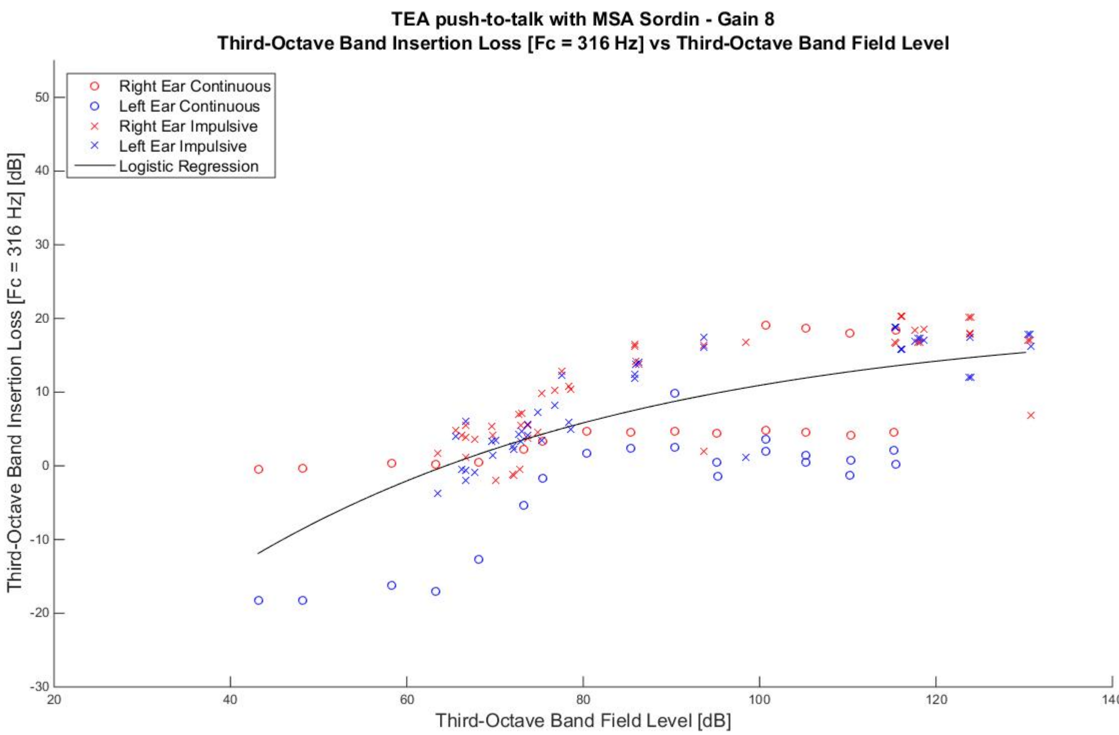

Figure A-323. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

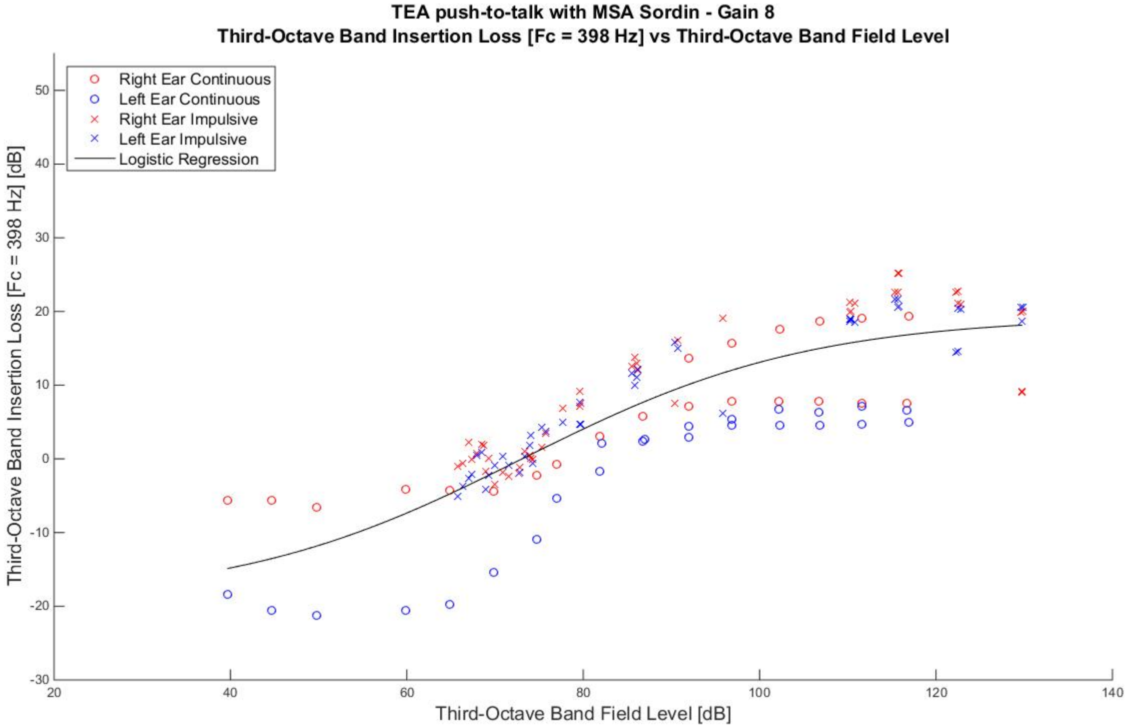

Figure A-324. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

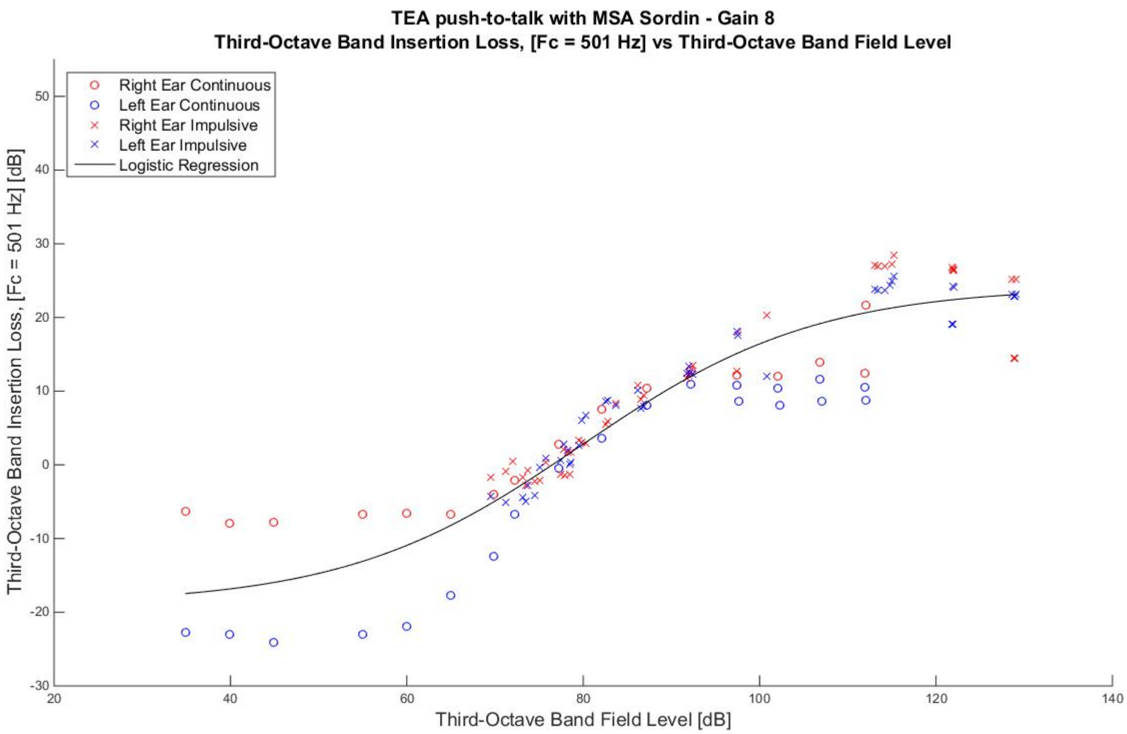

Figure A-325. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

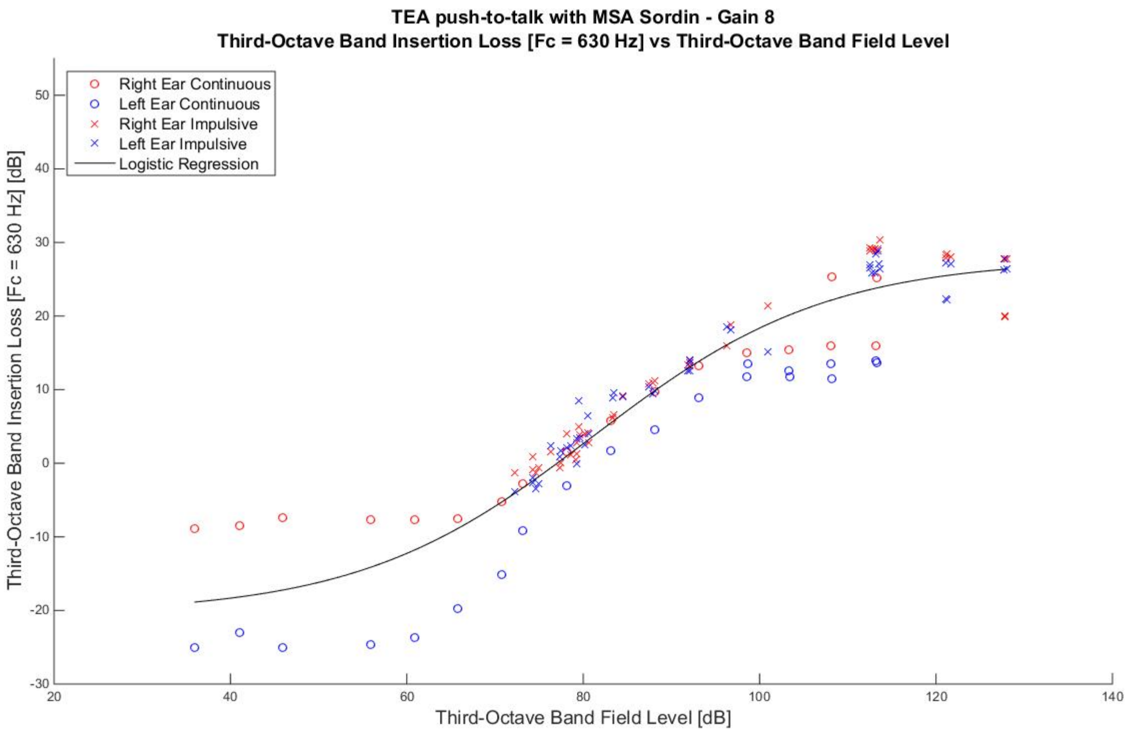

Figure A-326. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

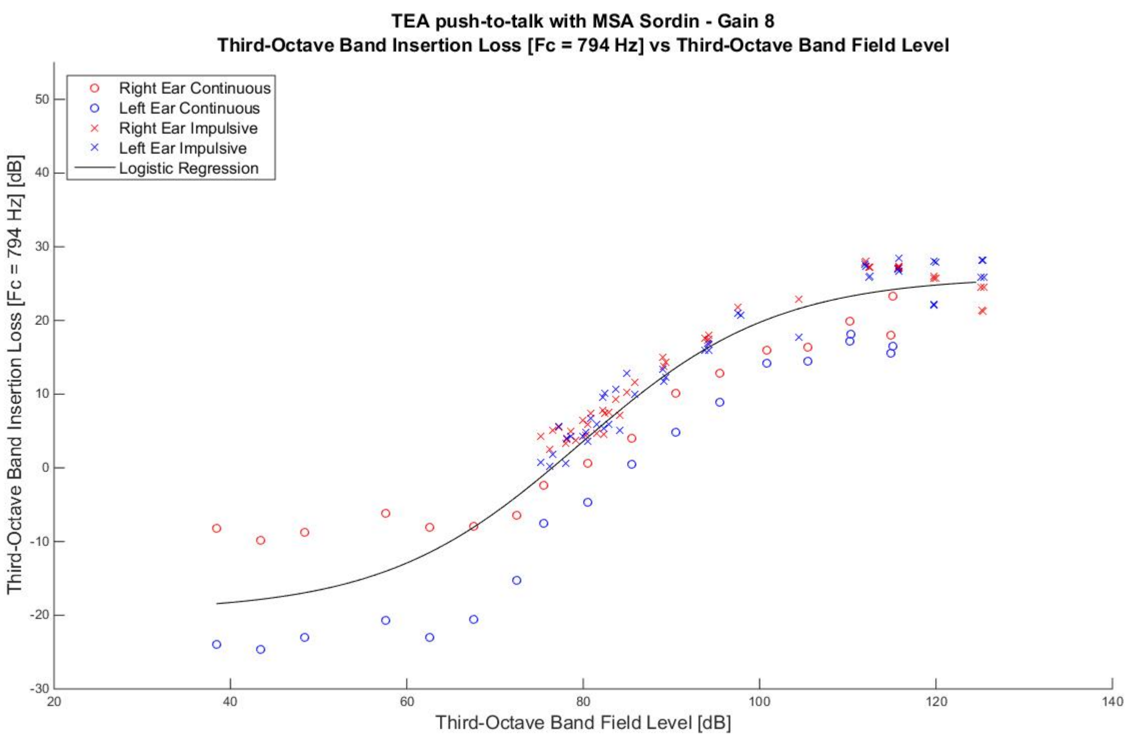

Figure A-327. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

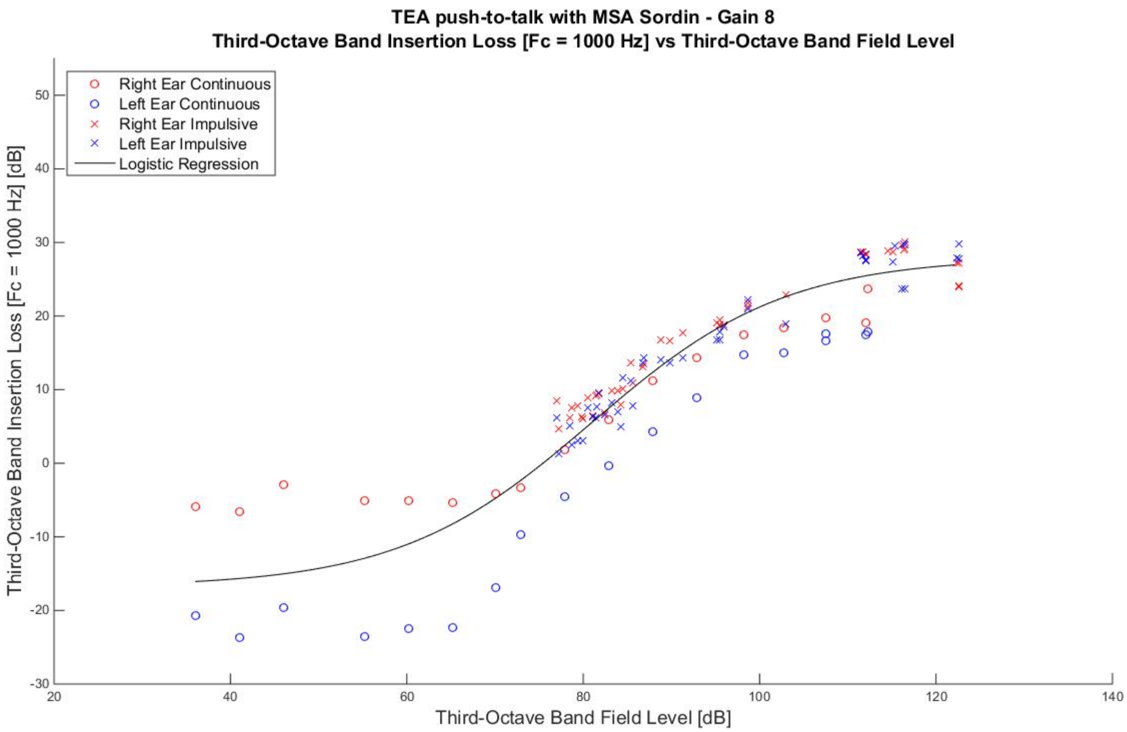

Figure A-328. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

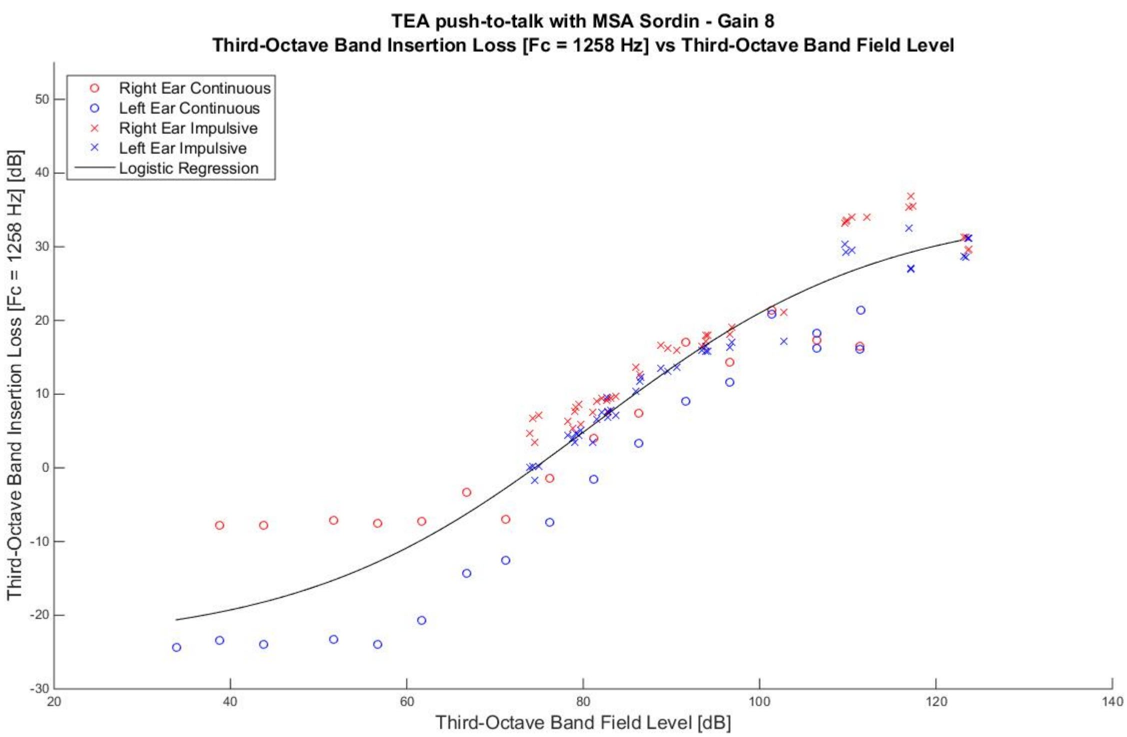

Figure A-329. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

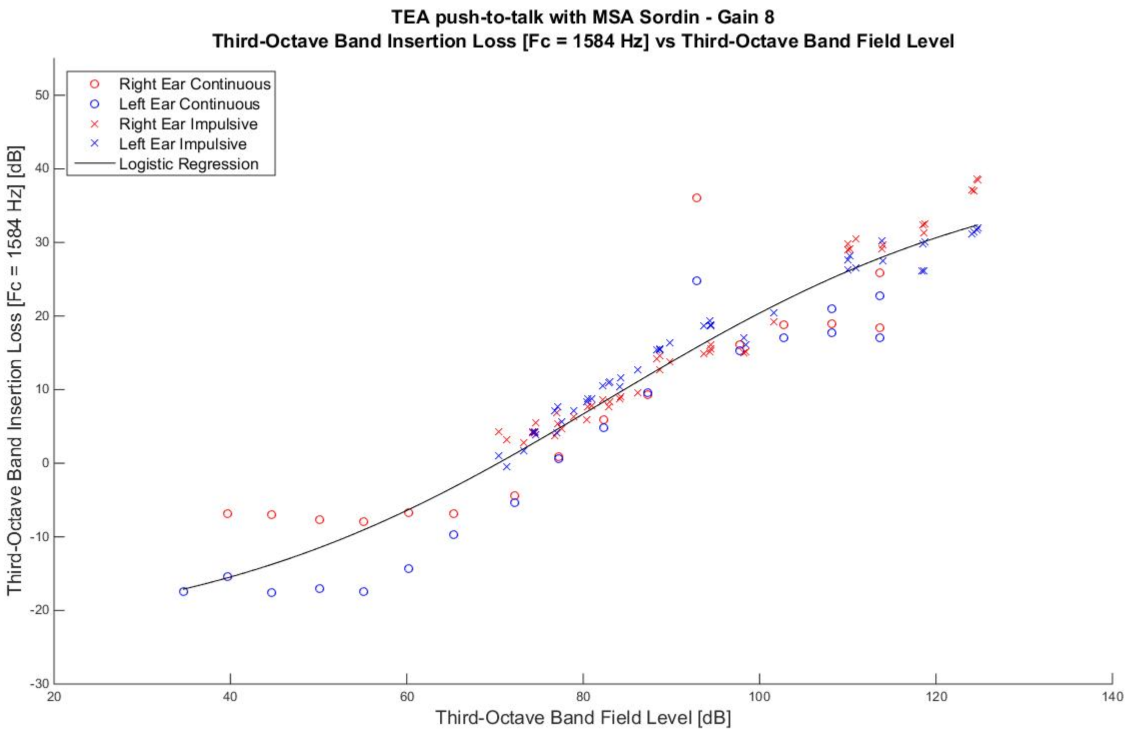

Figure A-330. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

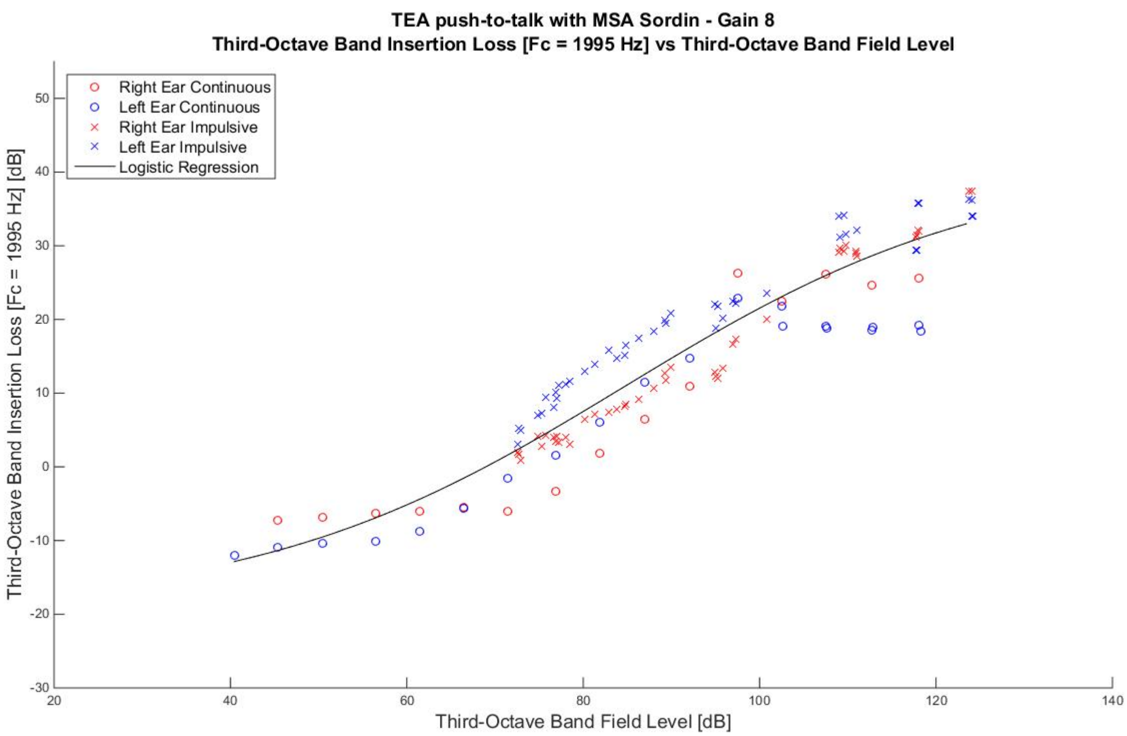

Figure A-331. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

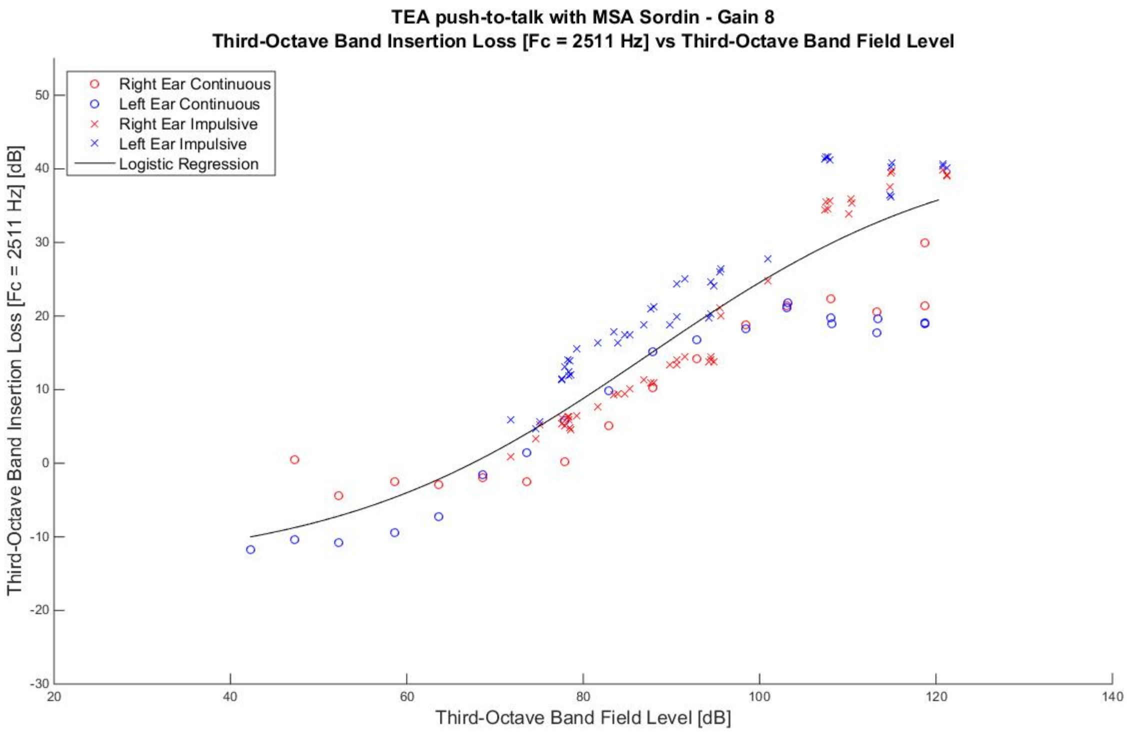

Figure A-332. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

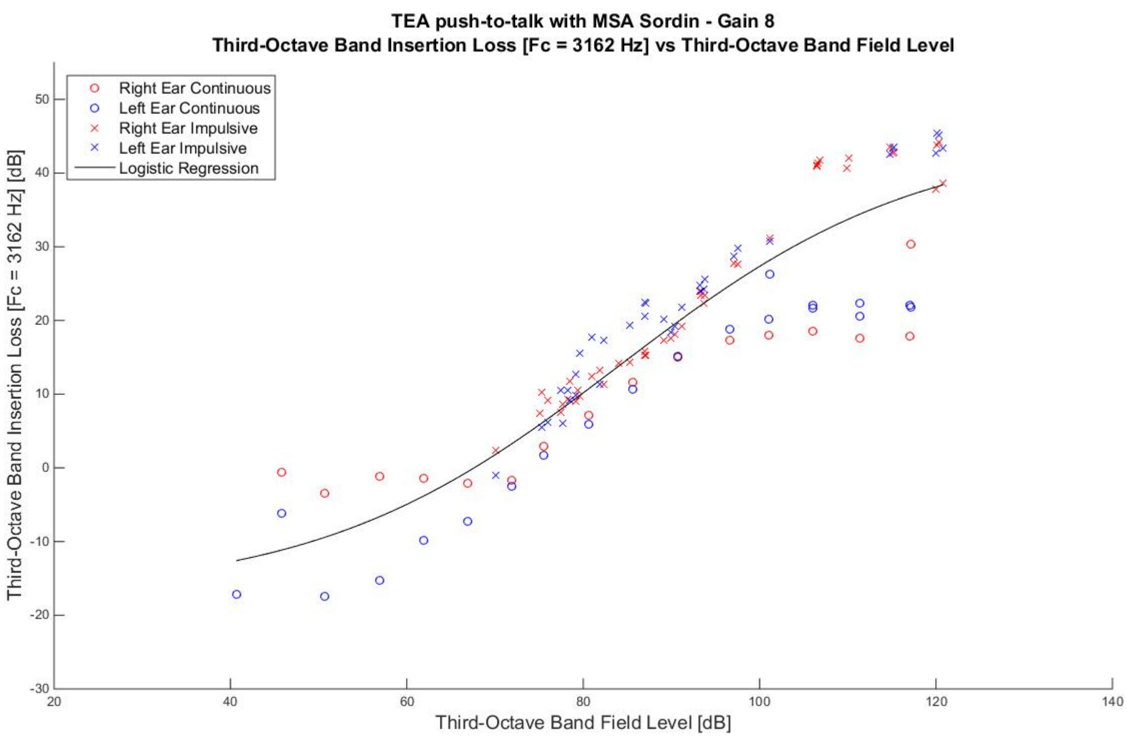

Figure A-333. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

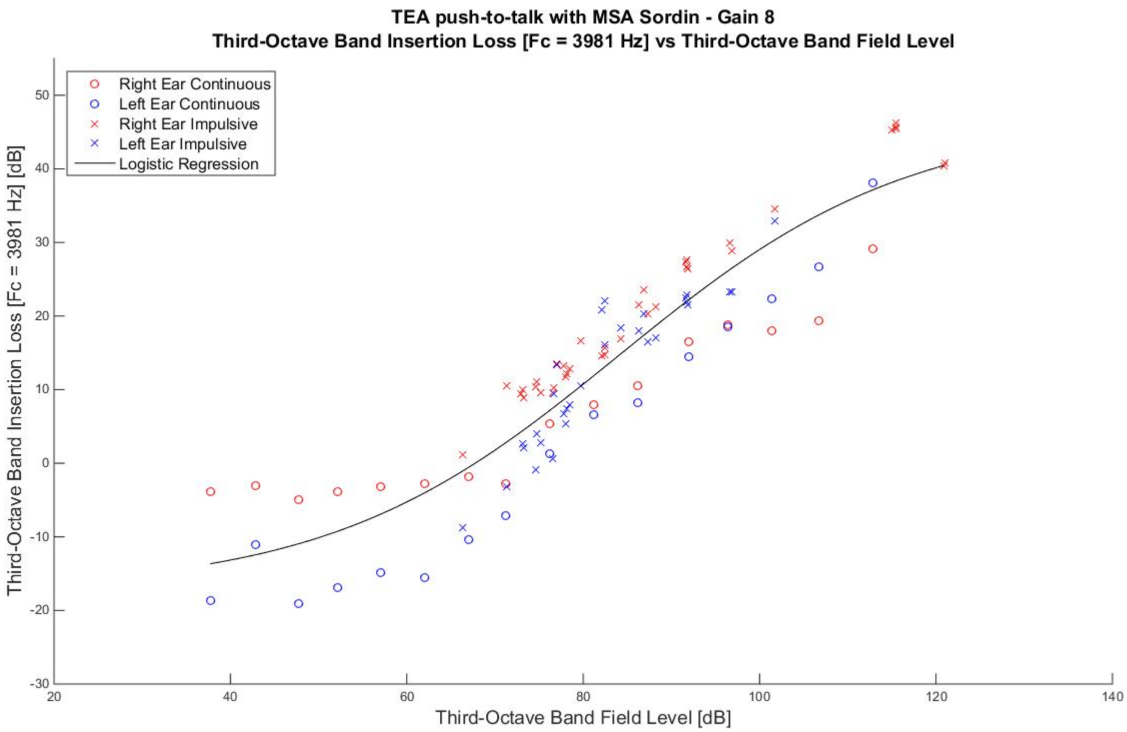

Figure A-334. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

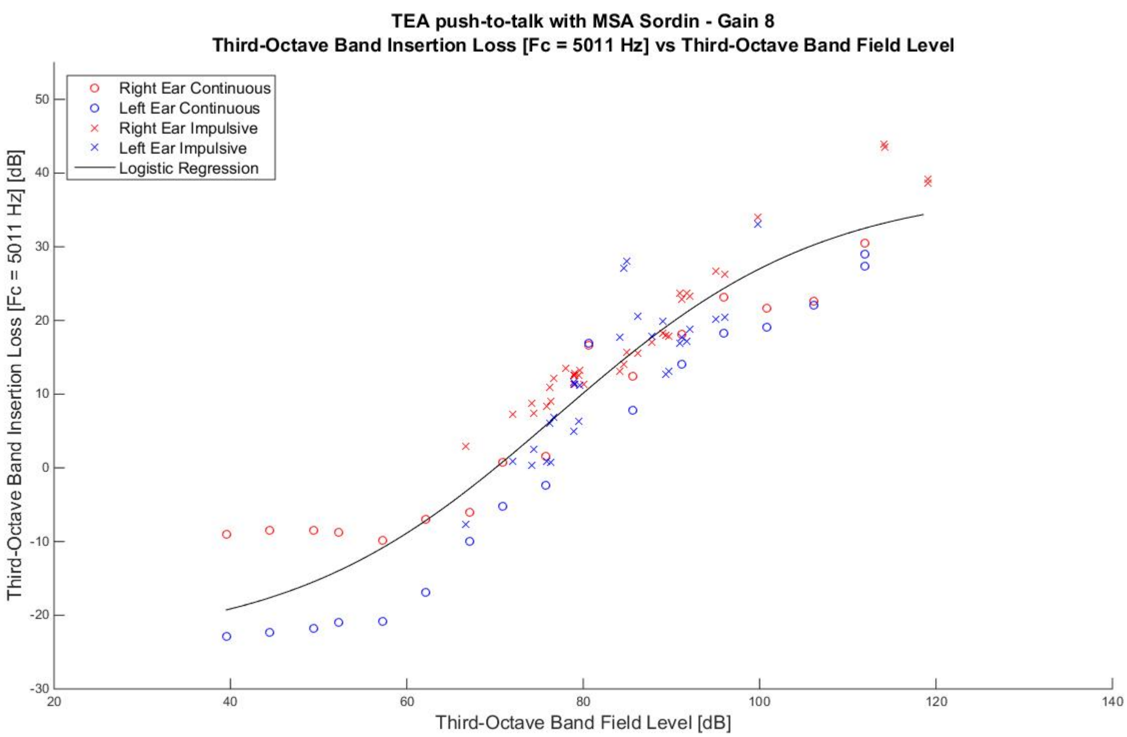

Figure A-335. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

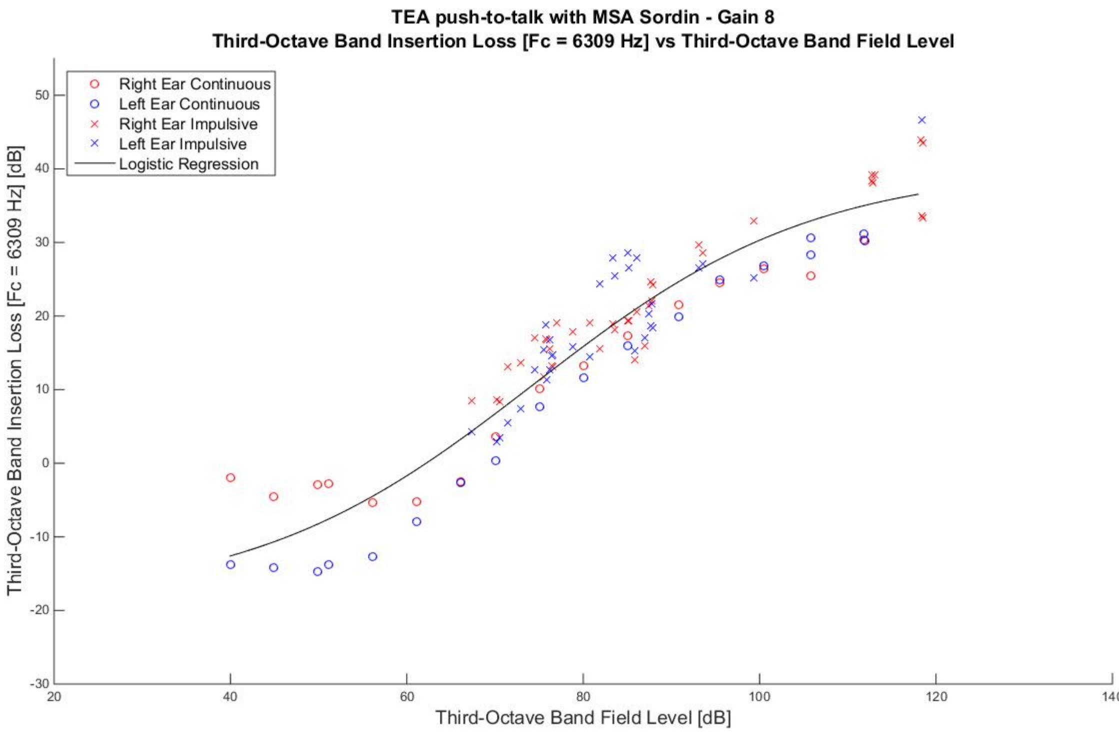

Figure A-336. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

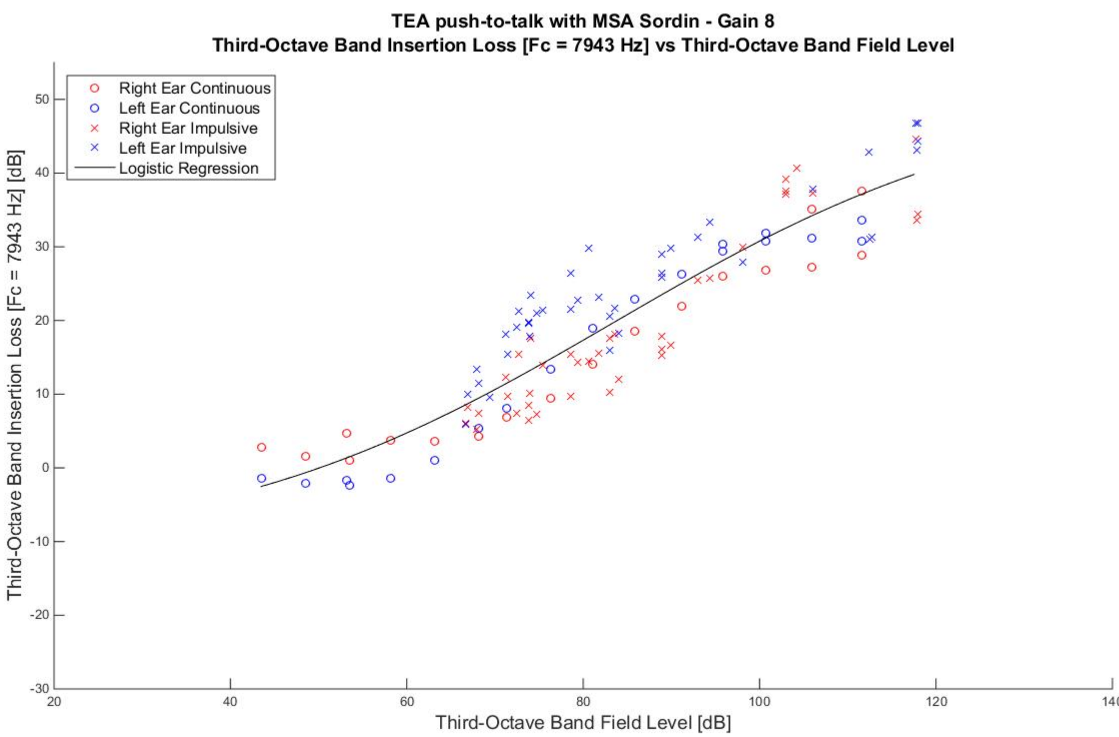

Figure A-337. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

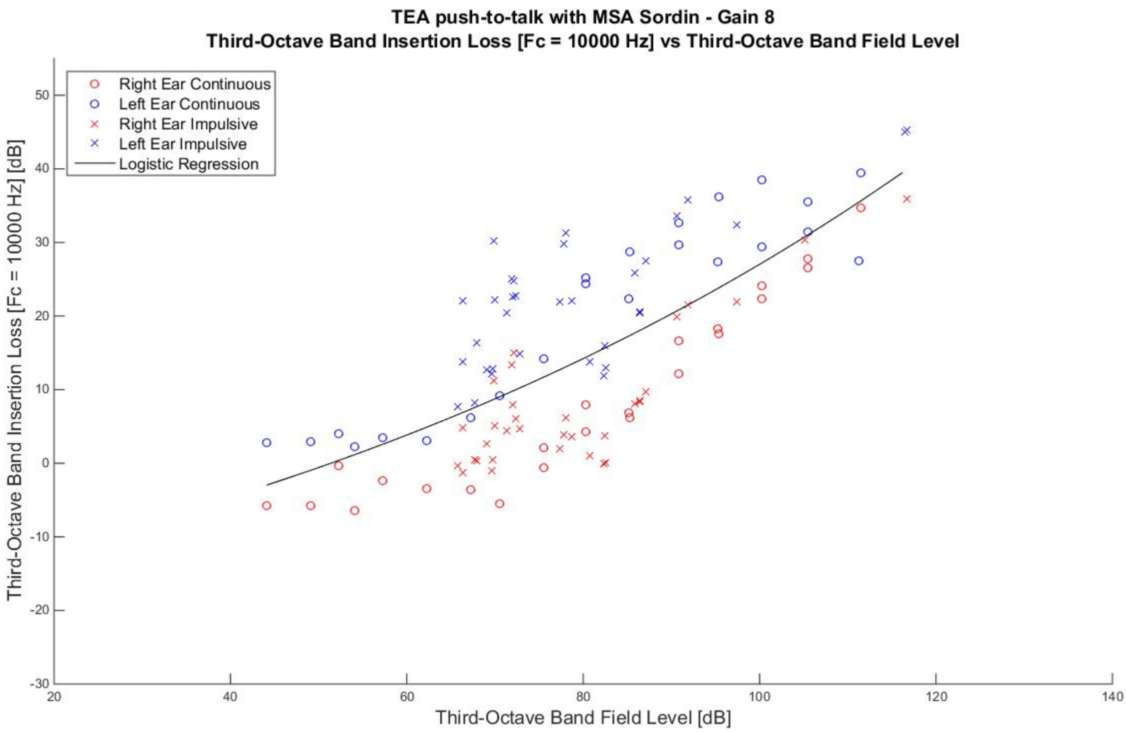

Figure A-338. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

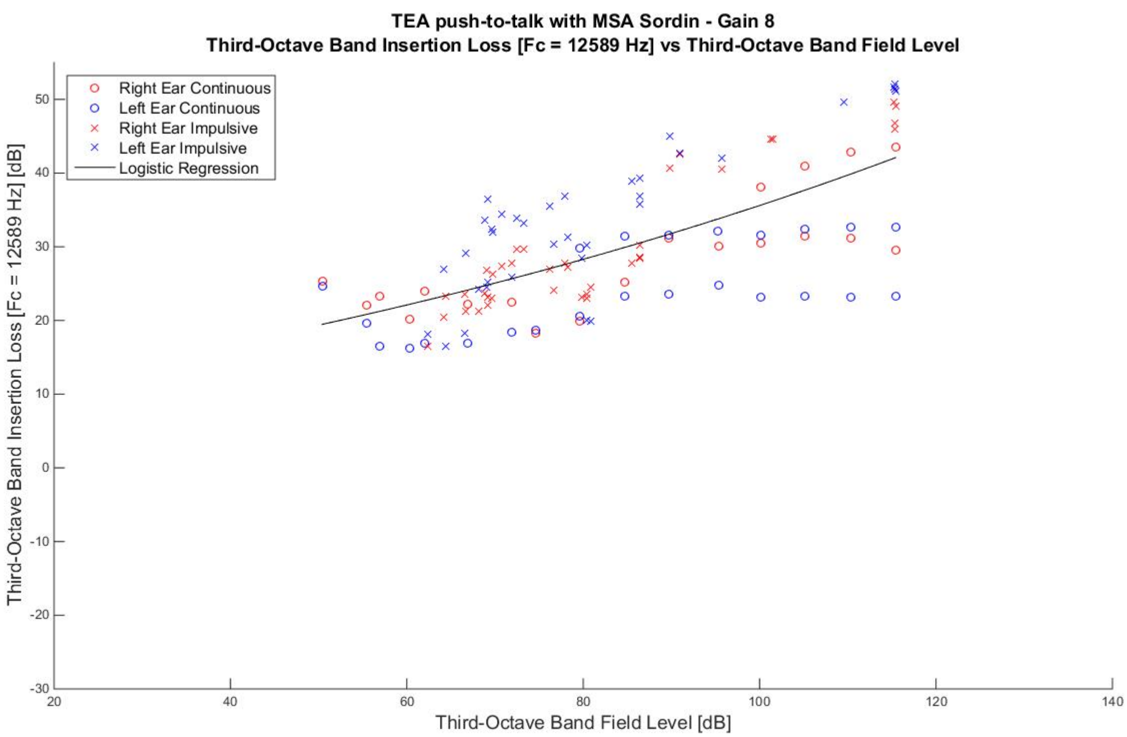

Figure A-339. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

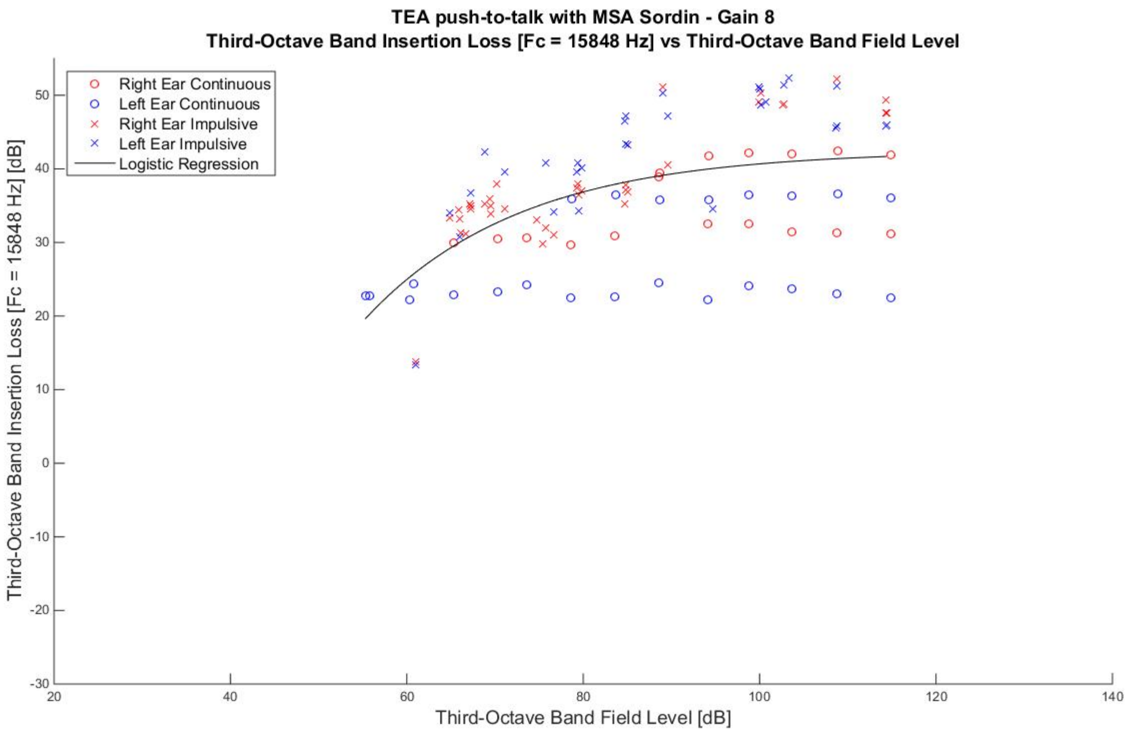

Figure A-340. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

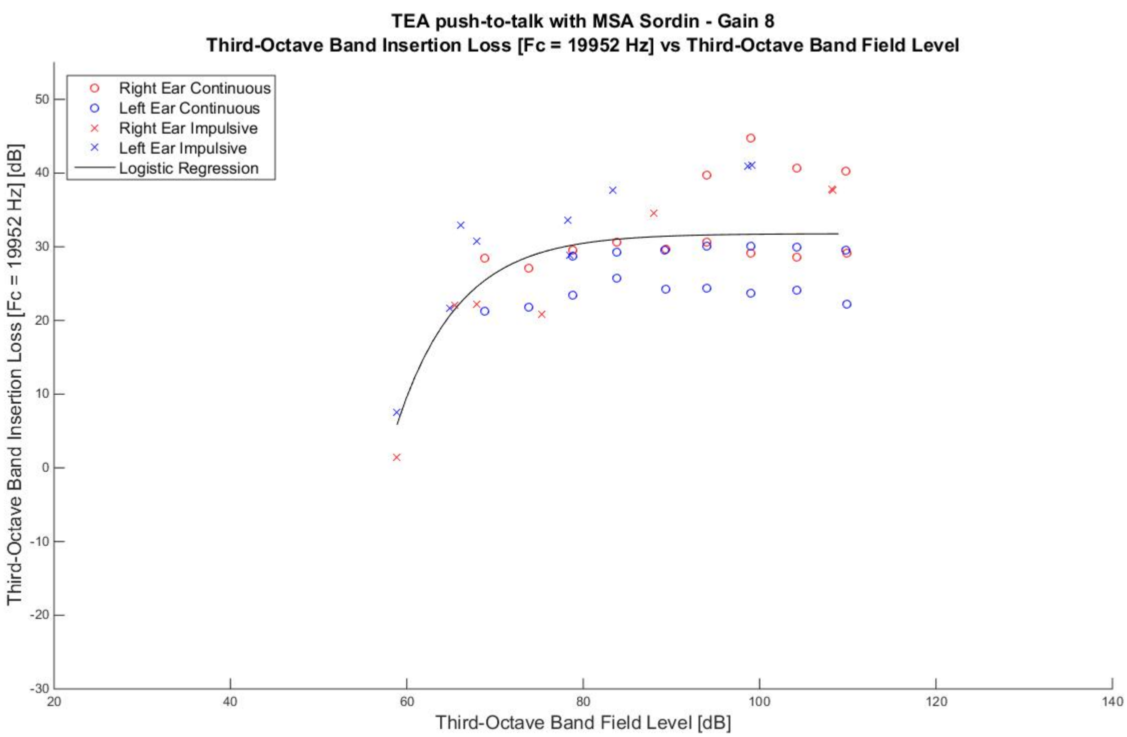

Figure A-341. MSA Sordin - Gain 8 - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

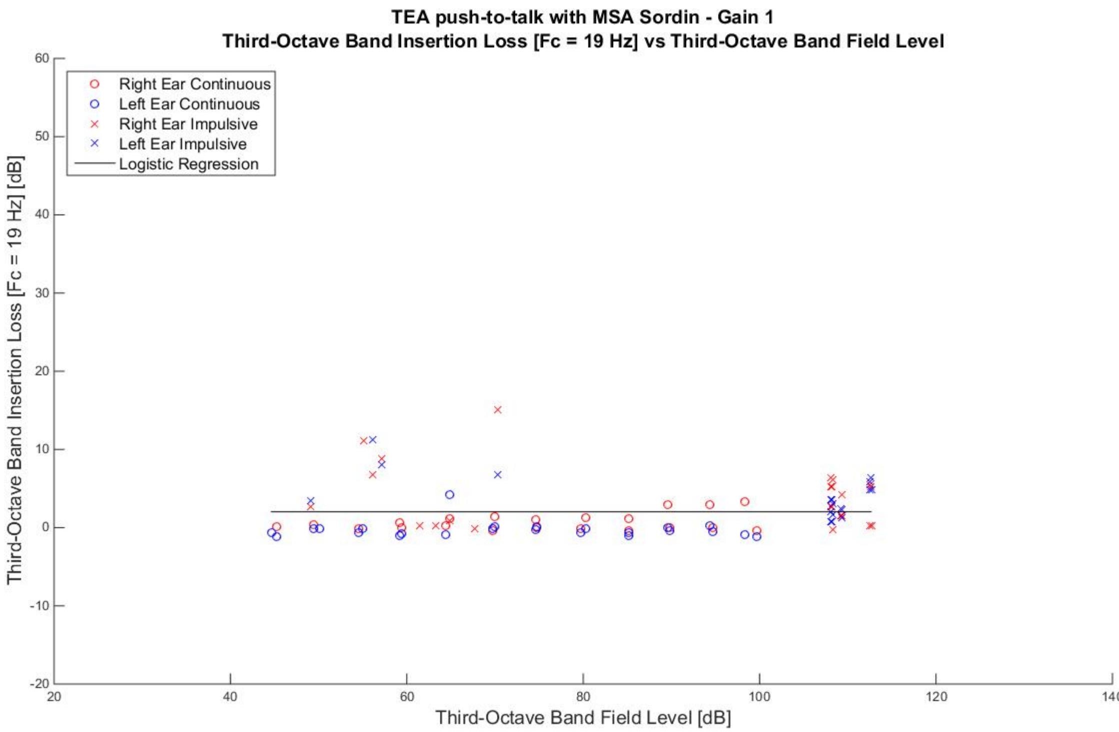

Figure A-342. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 19 Hz.

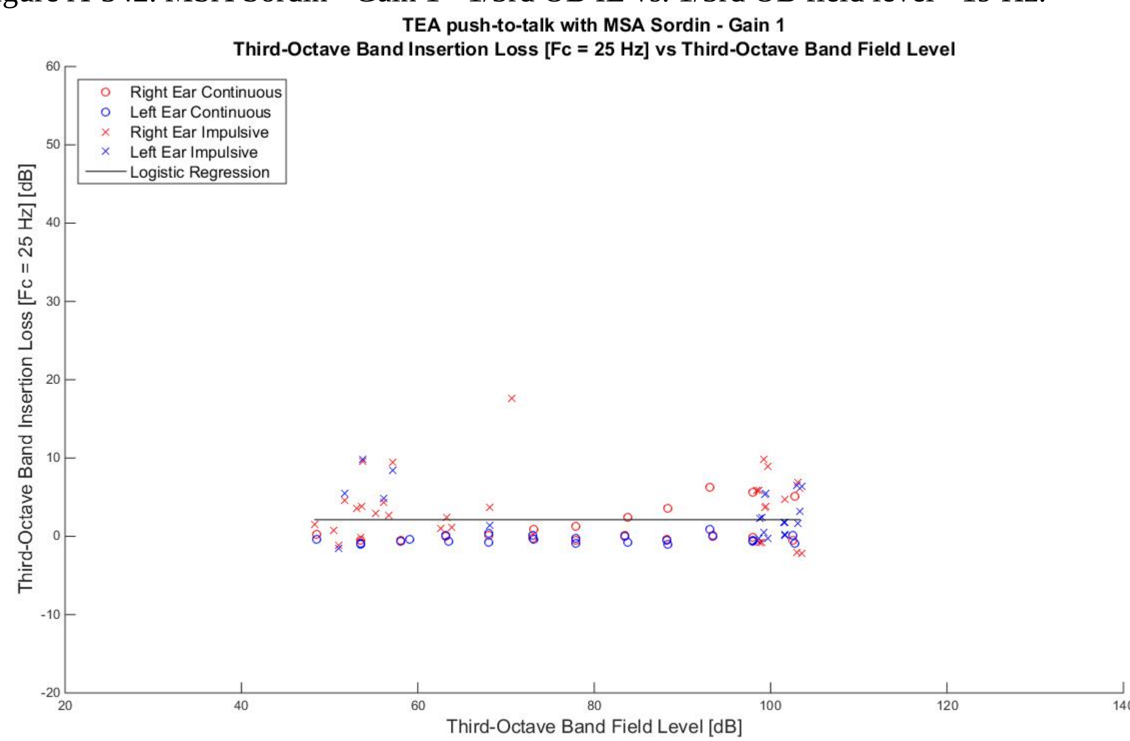

Figure A-343. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 25 Hz.

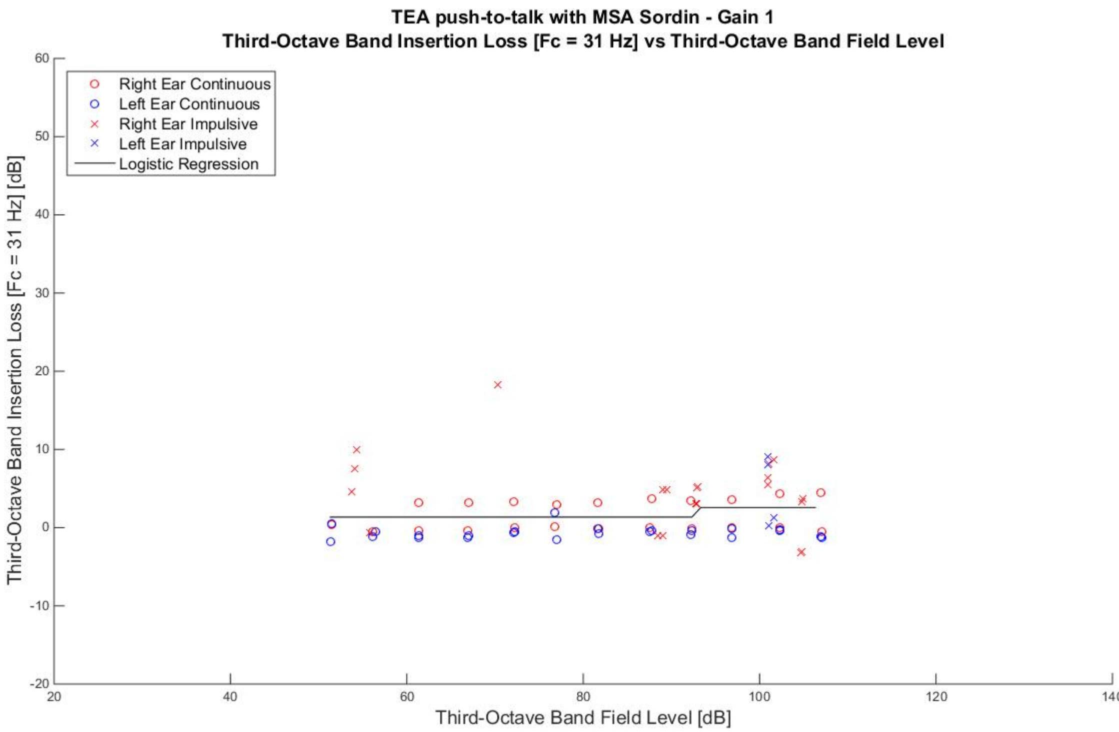

Figure A-344. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 31 Hz.

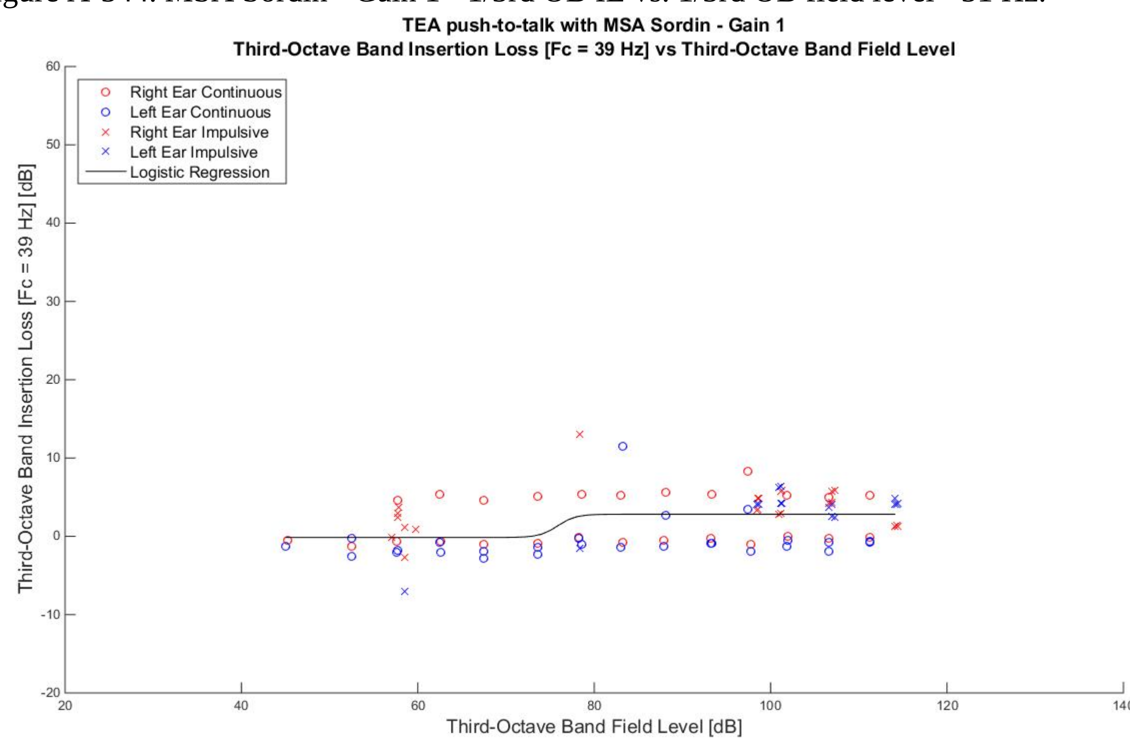

Figure A-345. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 39 Hz.

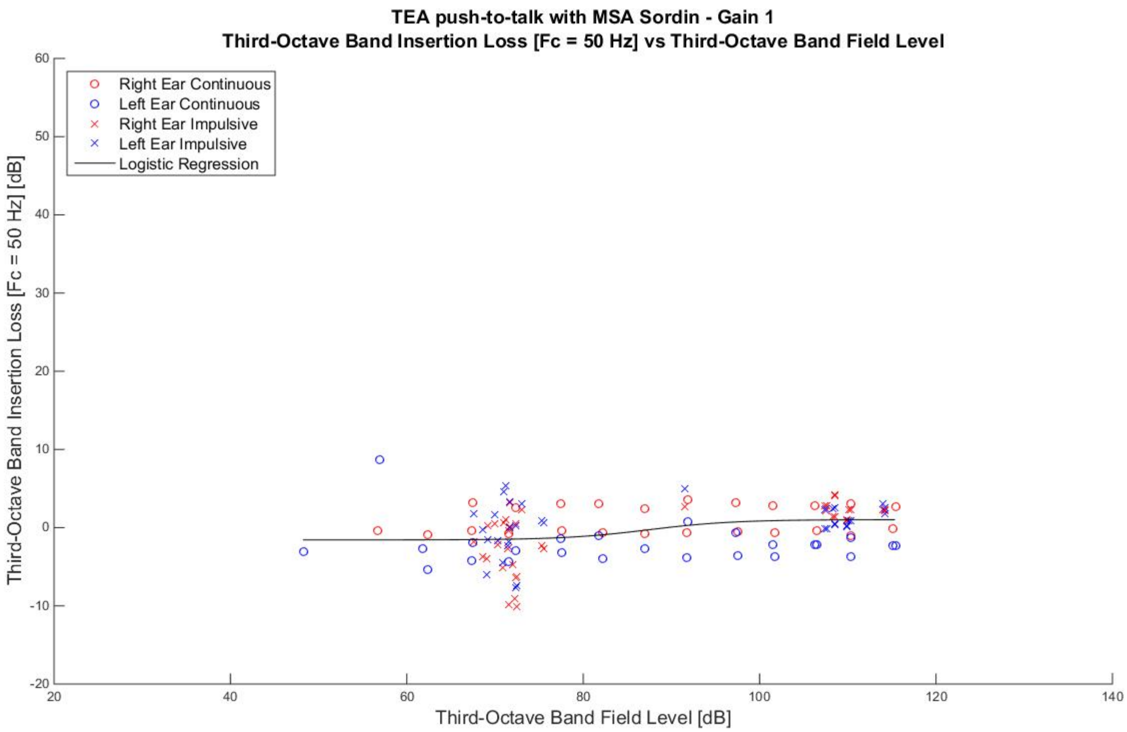

Figure A-346. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 50 Hz.

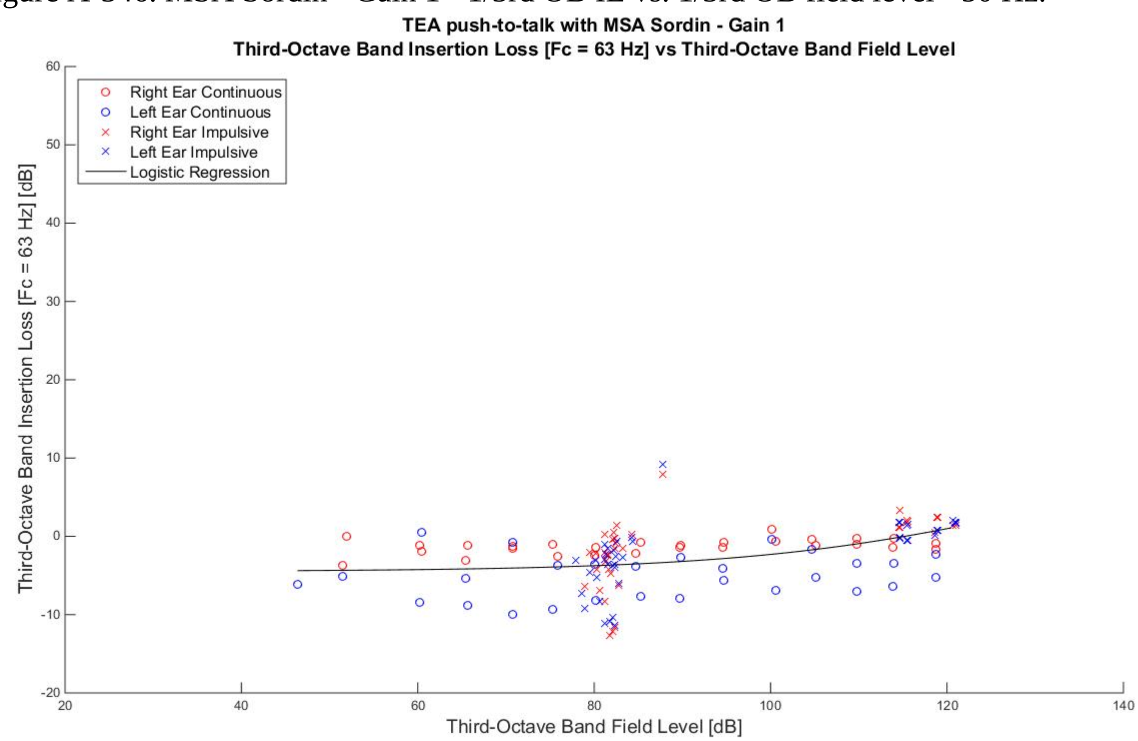

Figure A-347. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 63 Hz.

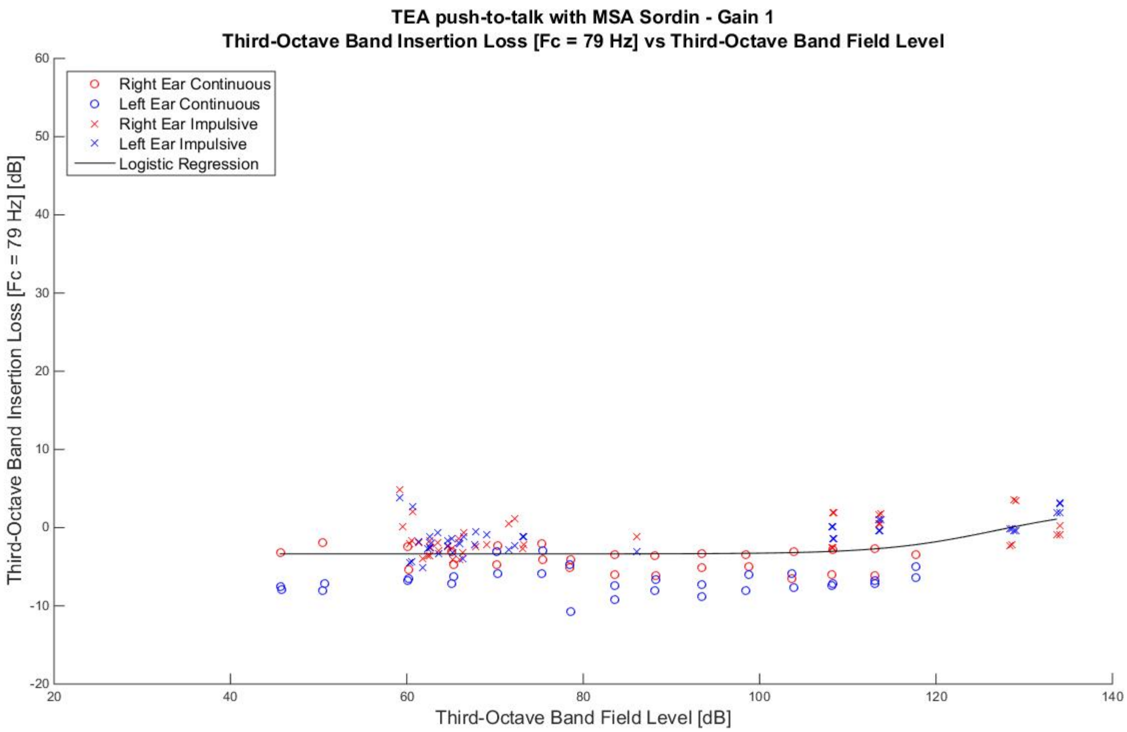

Figure A-348. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 79 Hz.

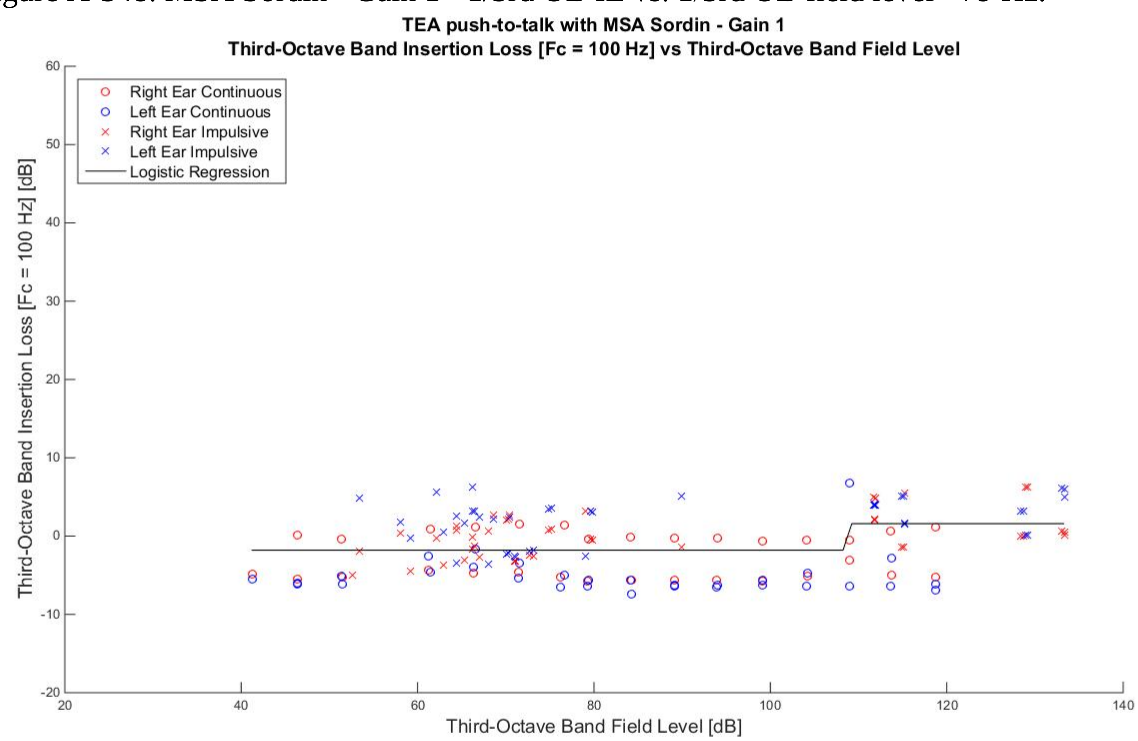

Figure A-349. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 100 Hz.

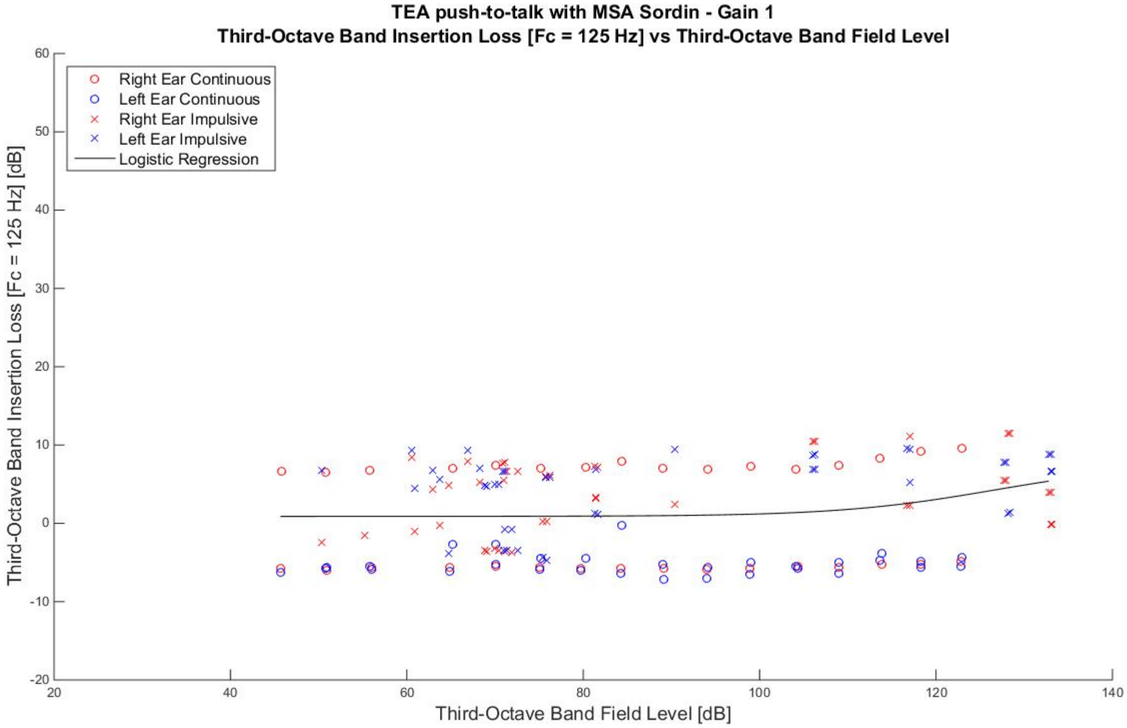

Figure A-350. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 125 Hz.

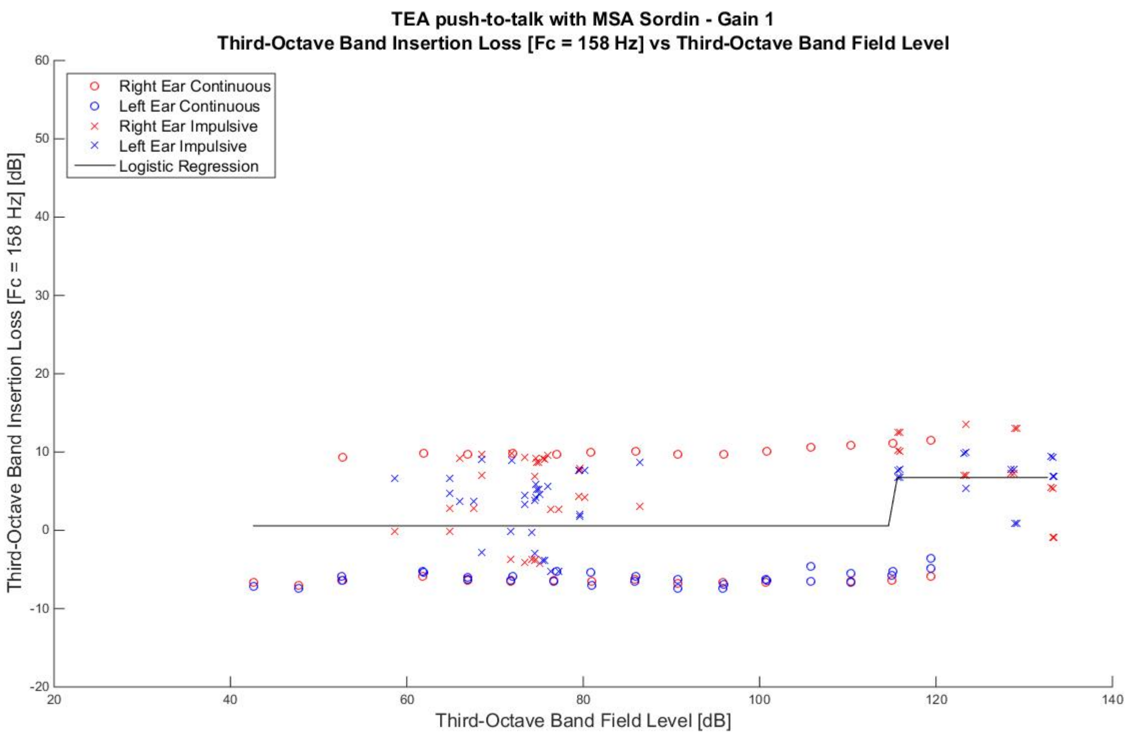

Figure A-351. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 158 Hz.

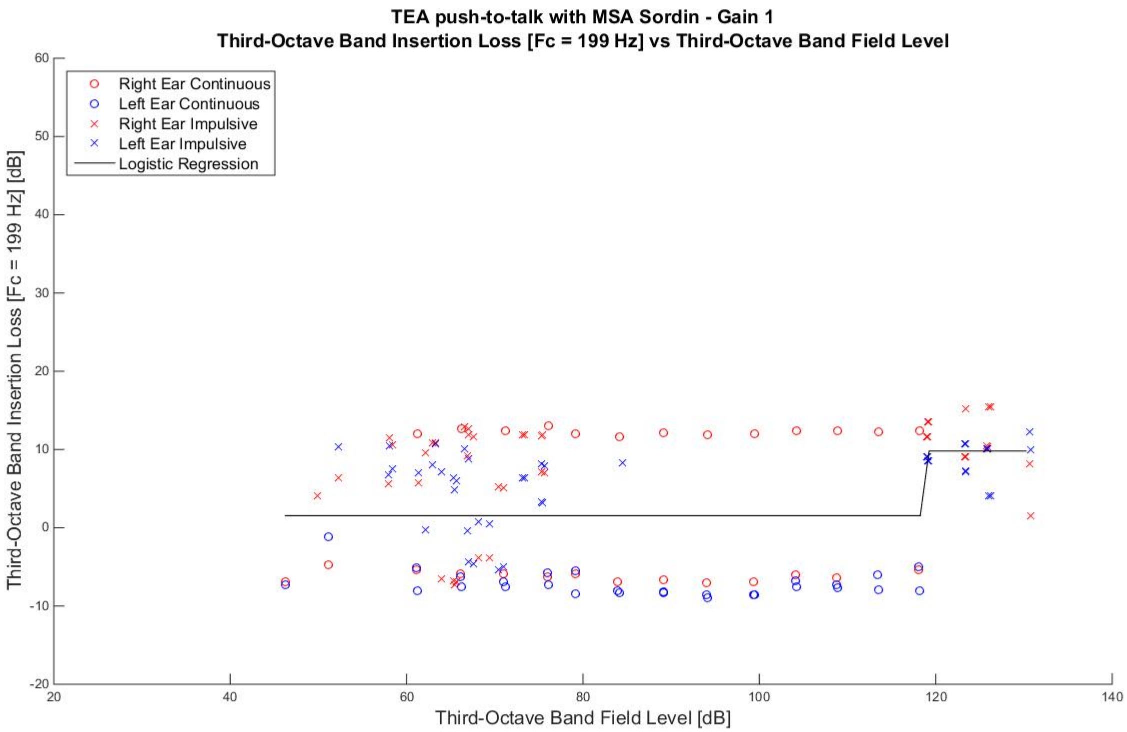

Figure A-352. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 199 Hz.

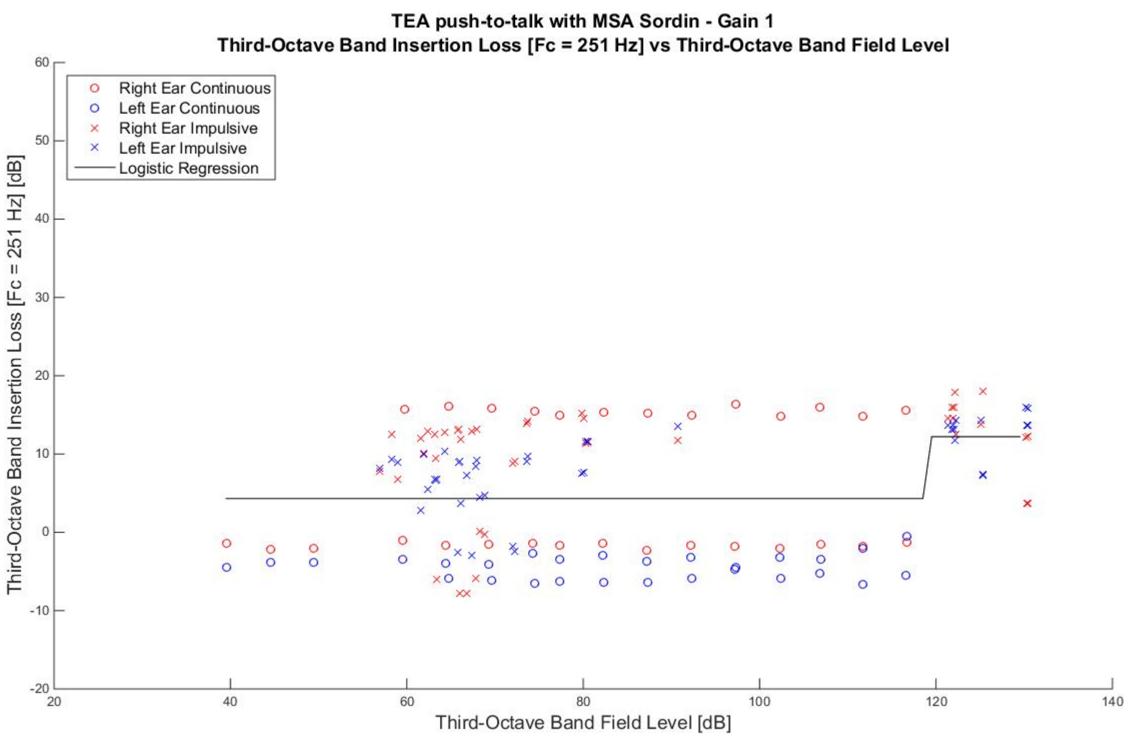

Figure A-353. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 251 Hz.

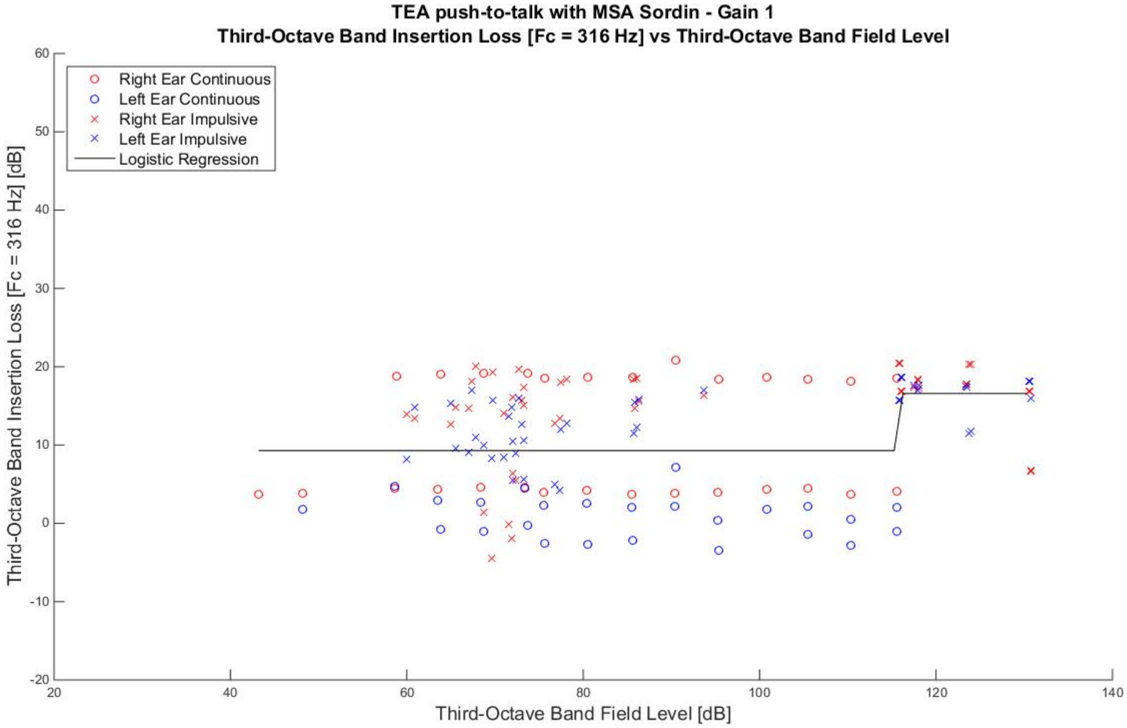

Figure A-354. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 316 Hz.

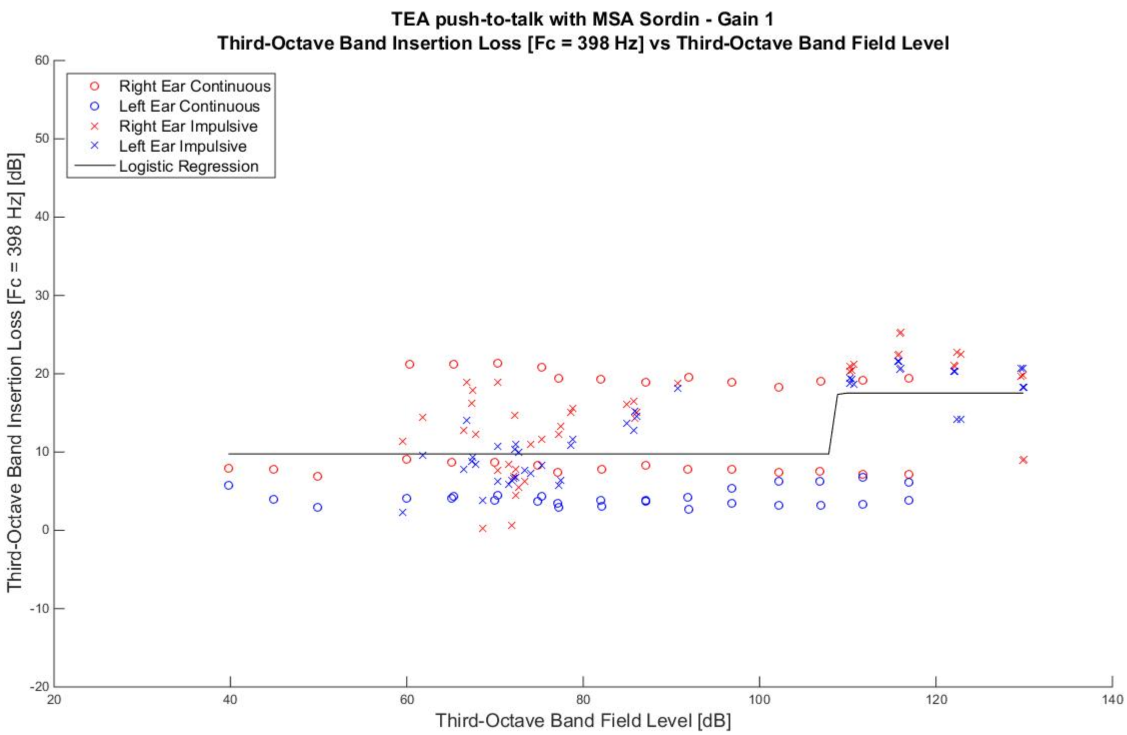

Figure A-355. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 398 Hz.

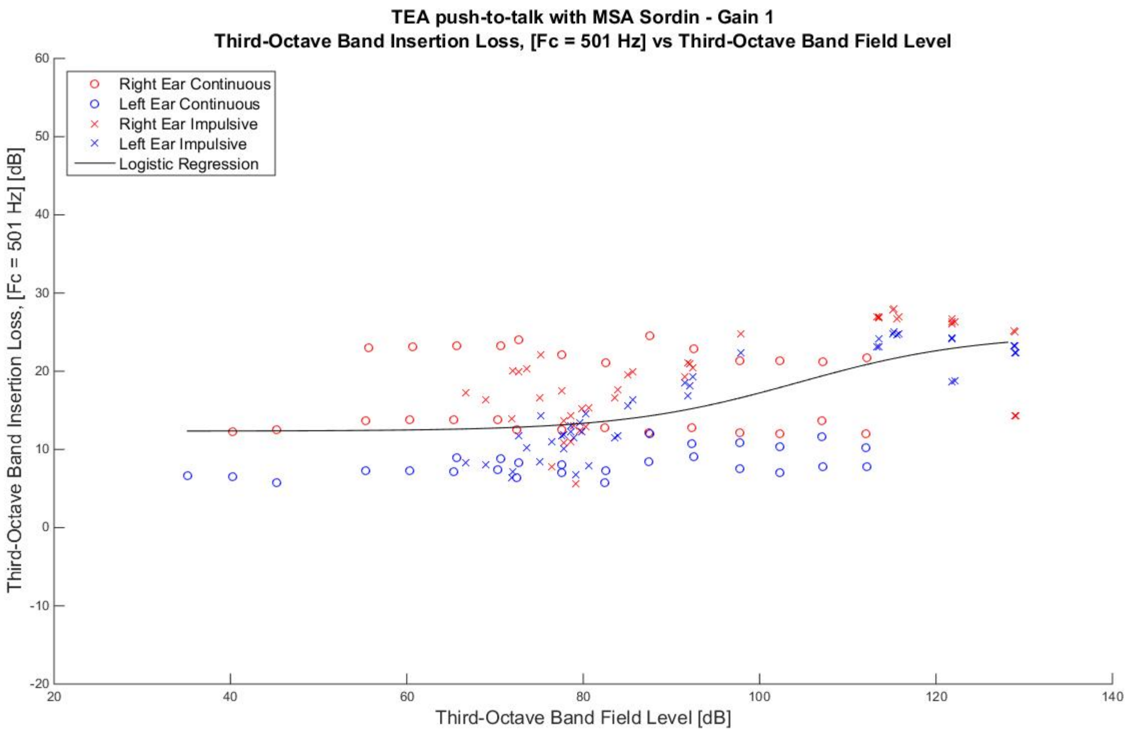

Figure A-356. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 501 Hz.

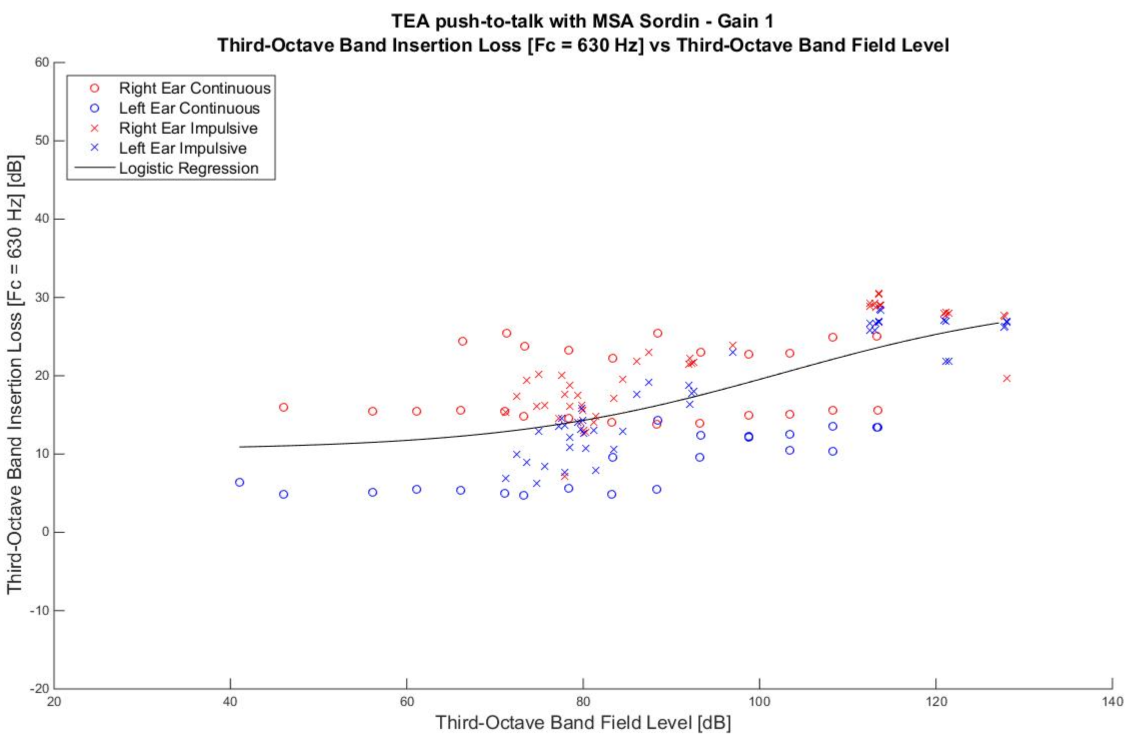

Figure A-357. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 630 Hz.

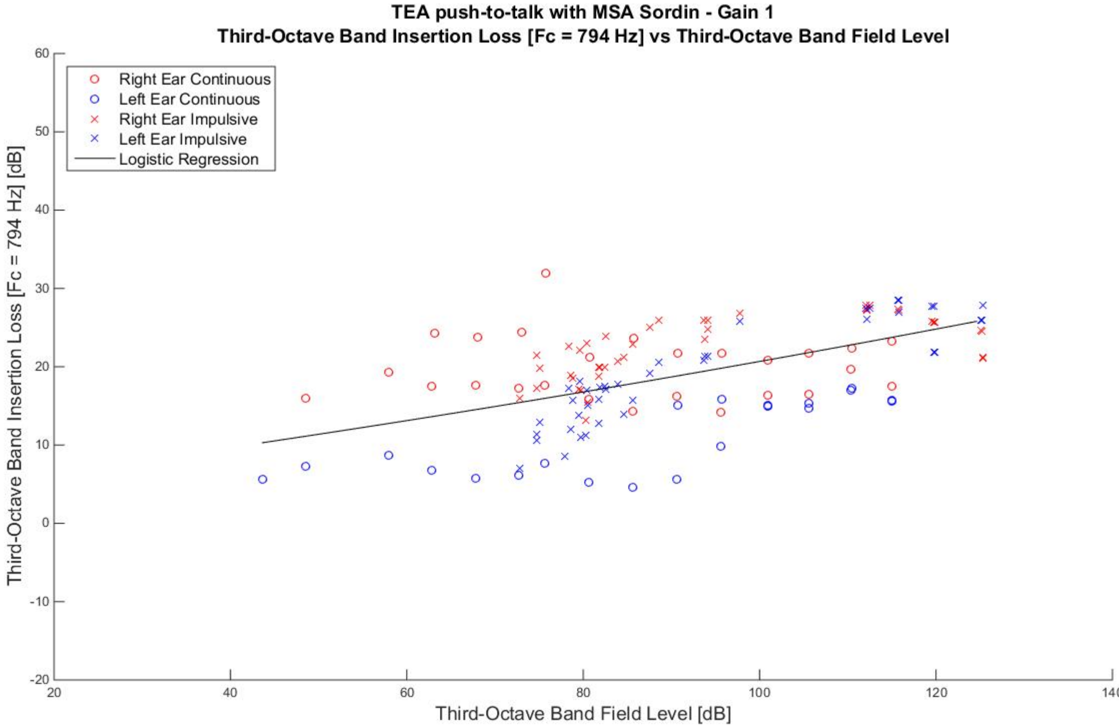

Figure A-358. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 794 Hz.

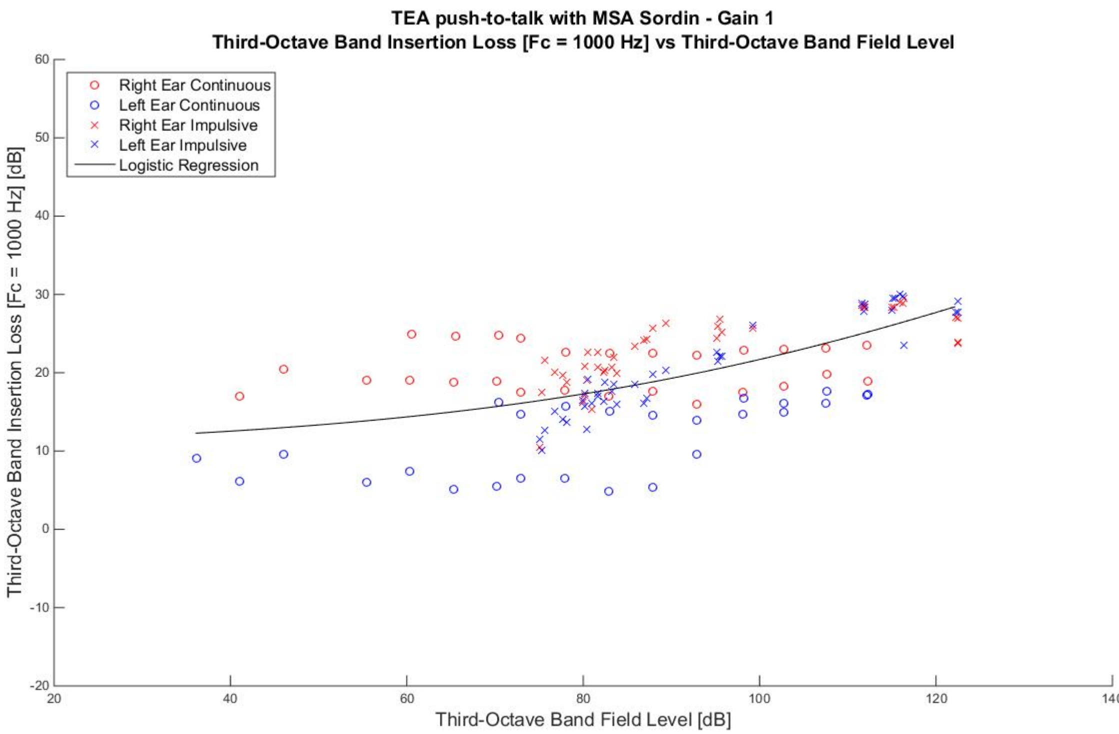

Figure A-359. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1000 Hz.

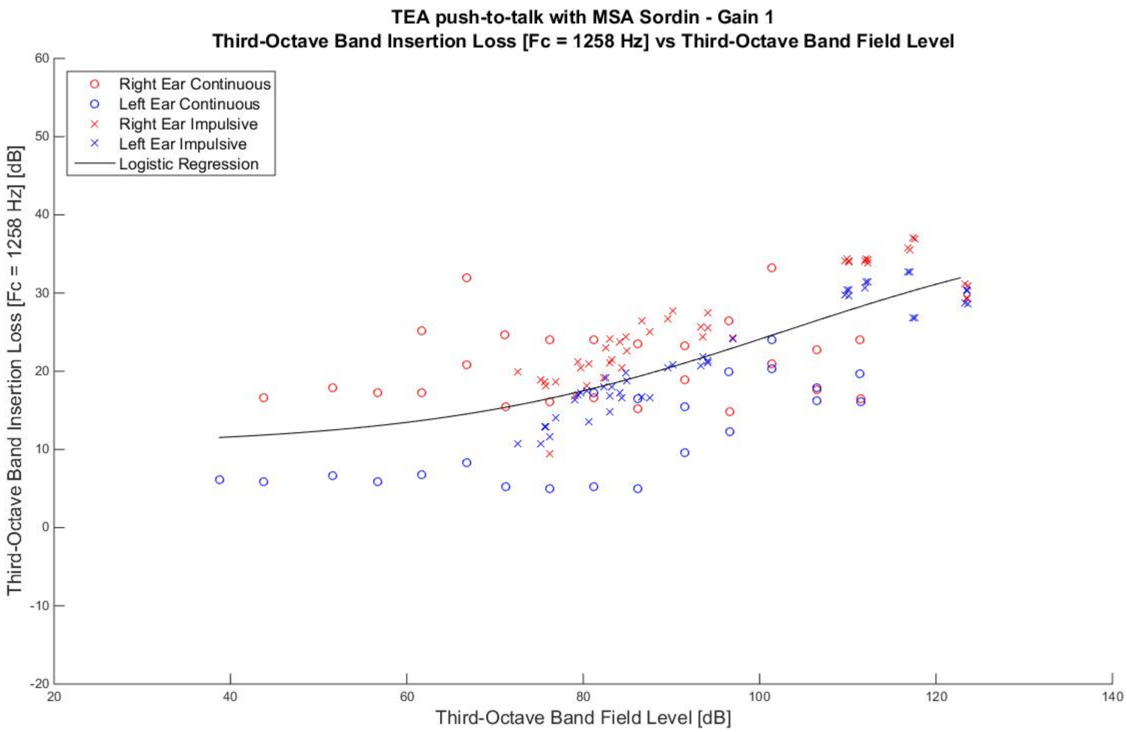

Figure A-360. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1258 Hz.

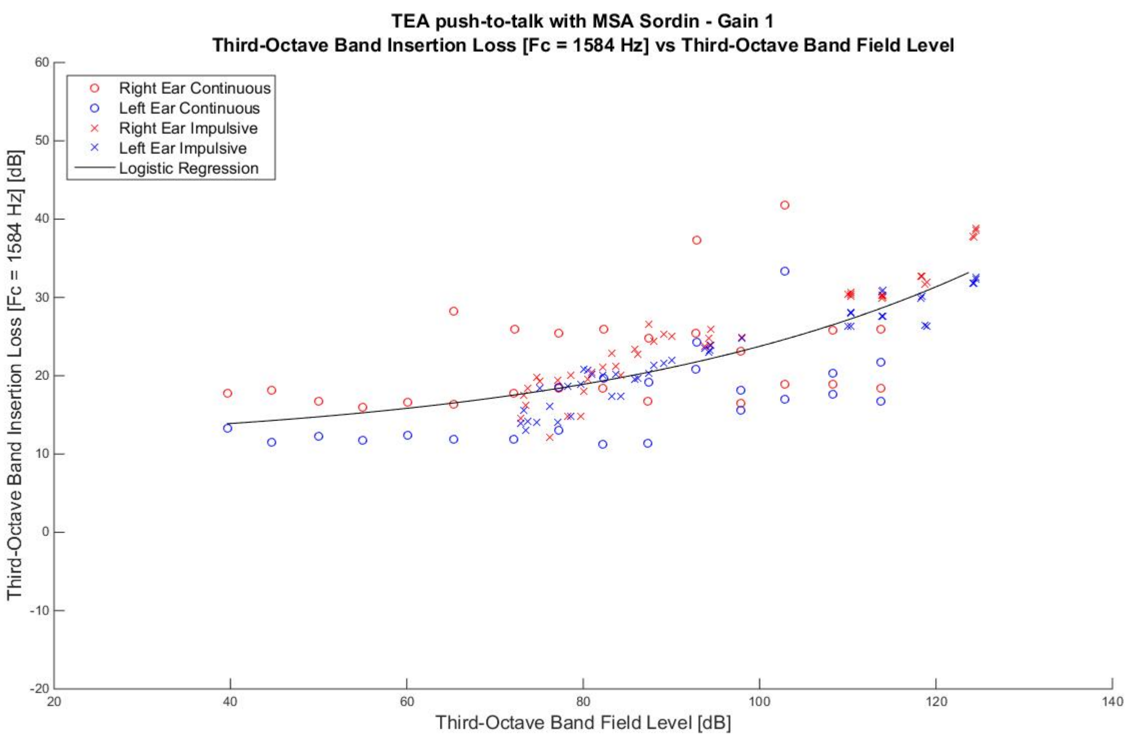

Figure A-361. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1584 Hz.

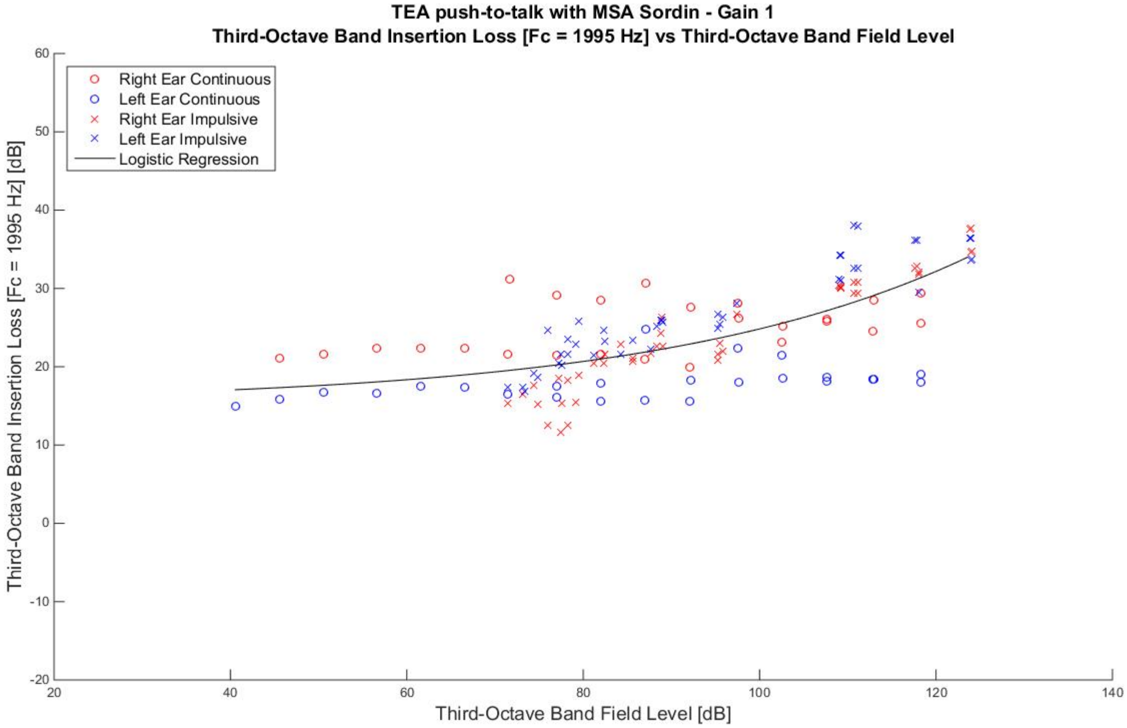

Figure A-362. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 1995 Hz.

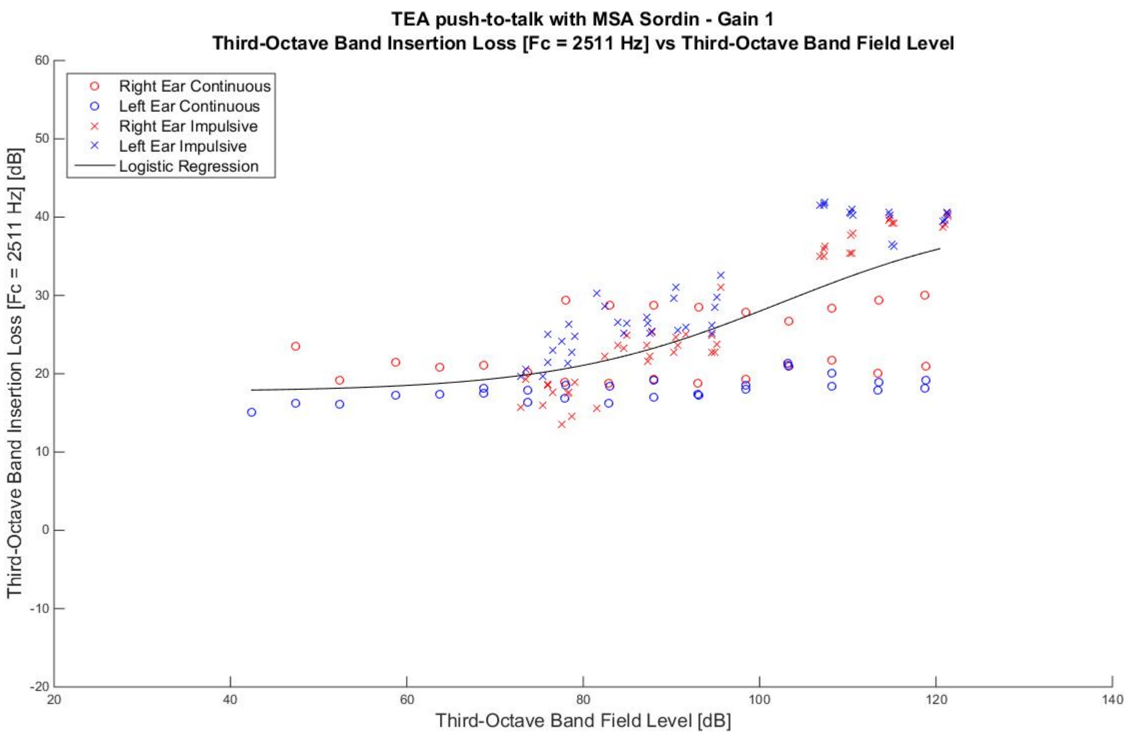

Figure A-363. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 2511 Hz.

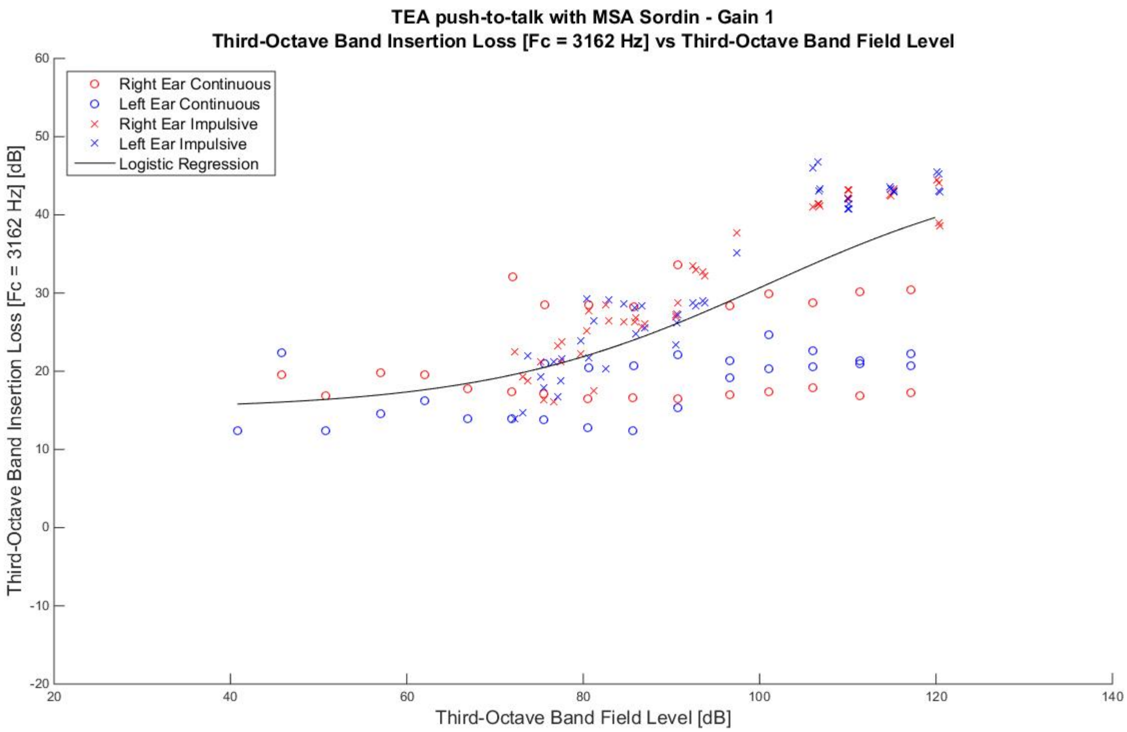

Figure A-364. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 3162 Hz.

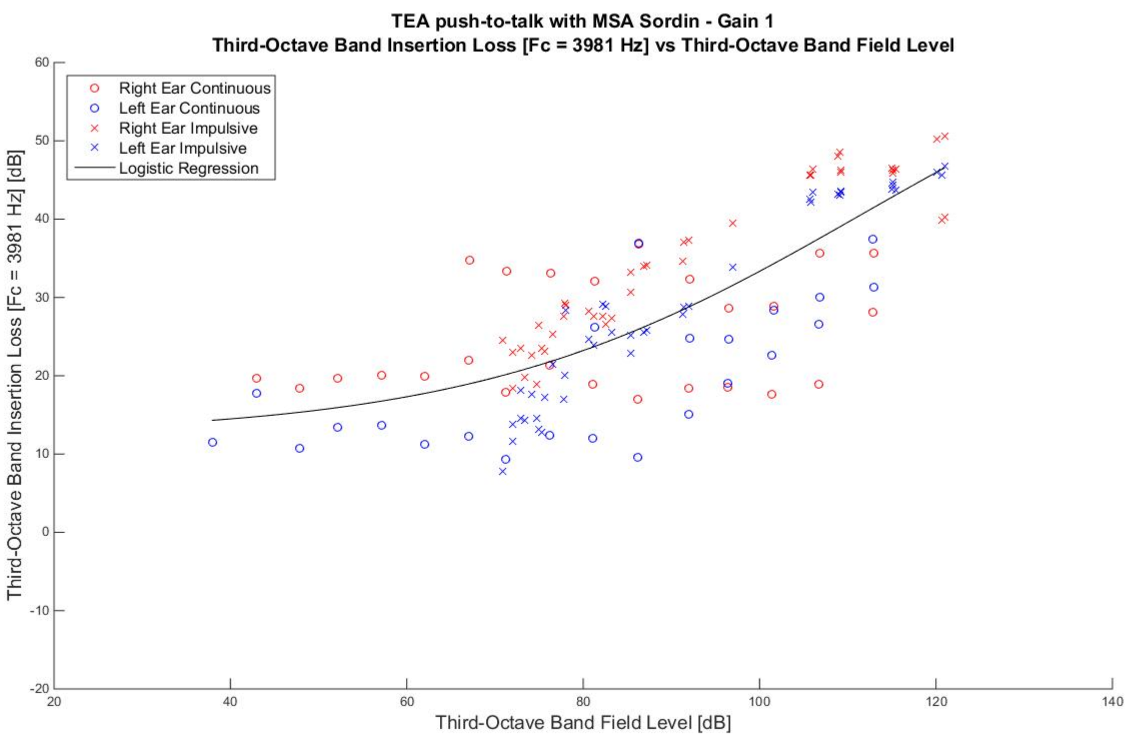

Figure A-365. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 3981 Hz.

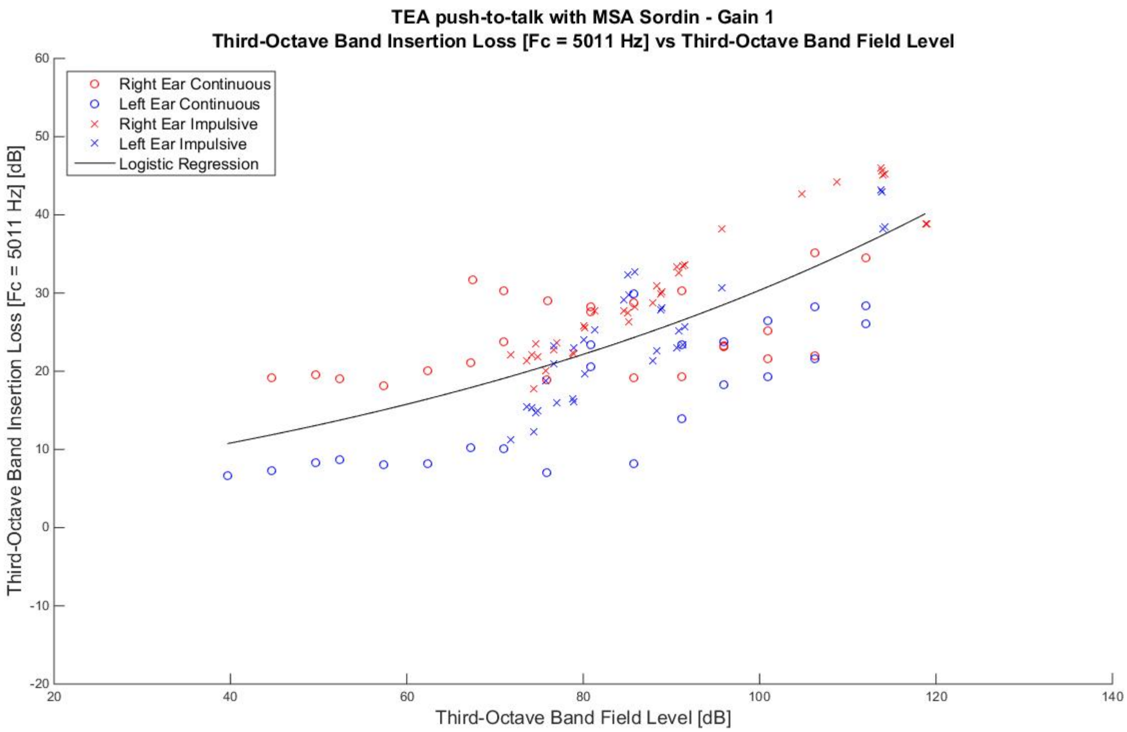

Figure A-366. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 5011 Hz.

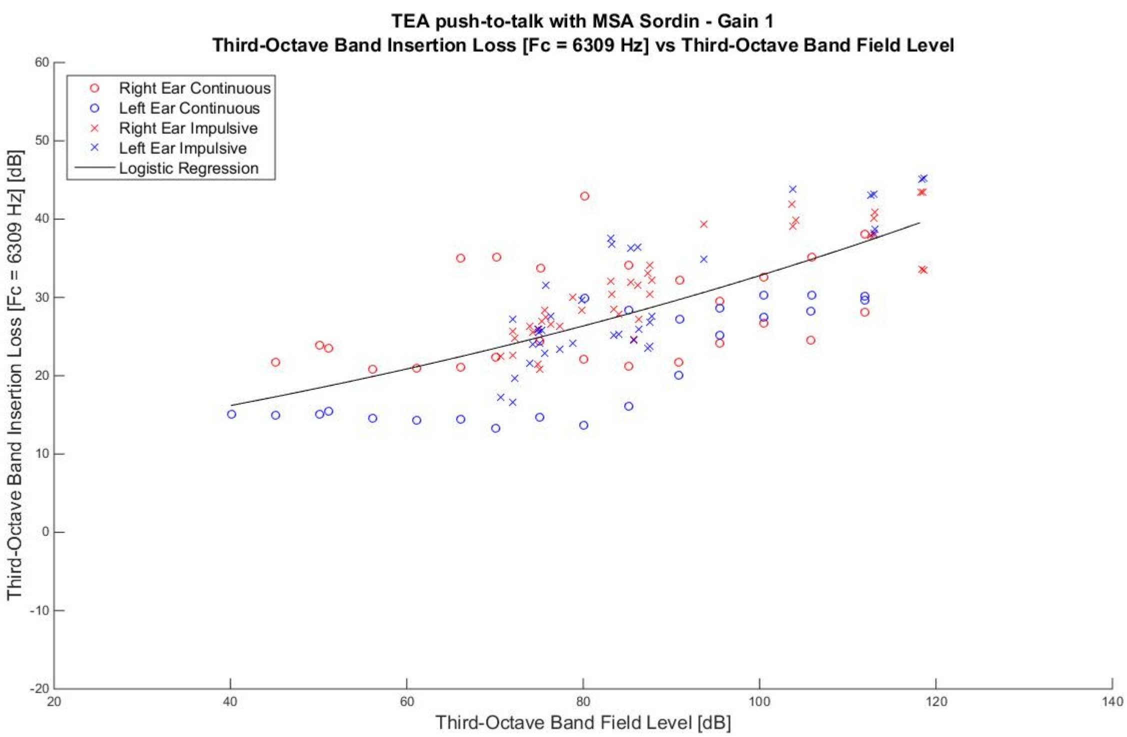

Figure A-367. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 6309 Hz.

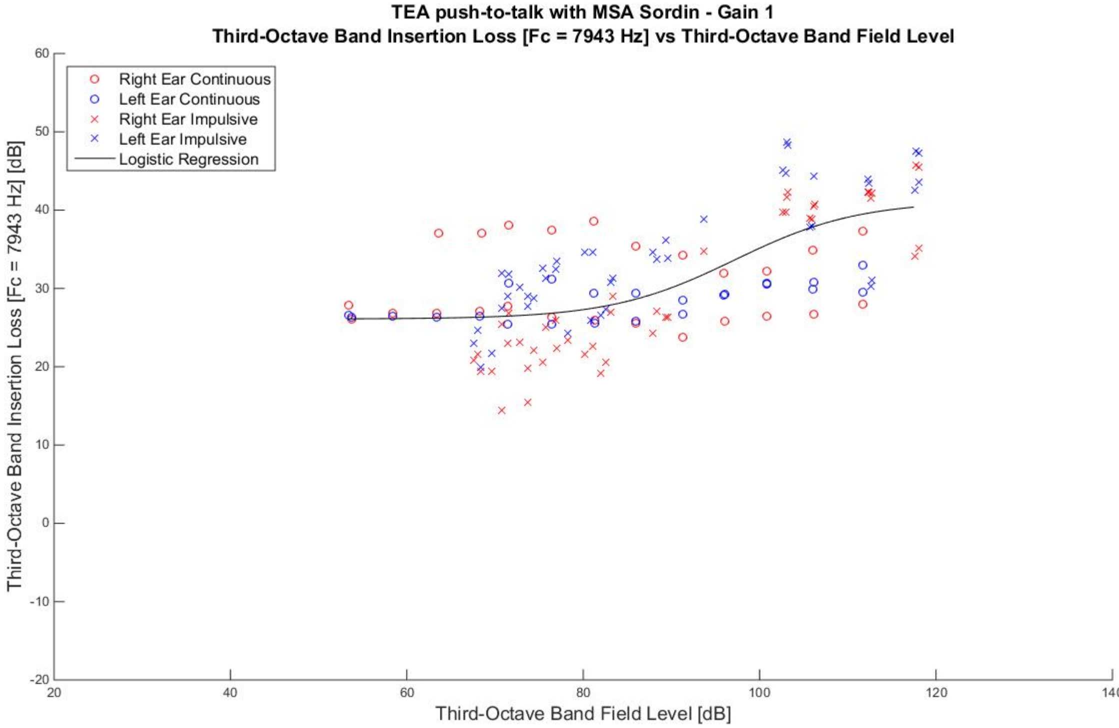

Figure A-368. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 7943 Hz.

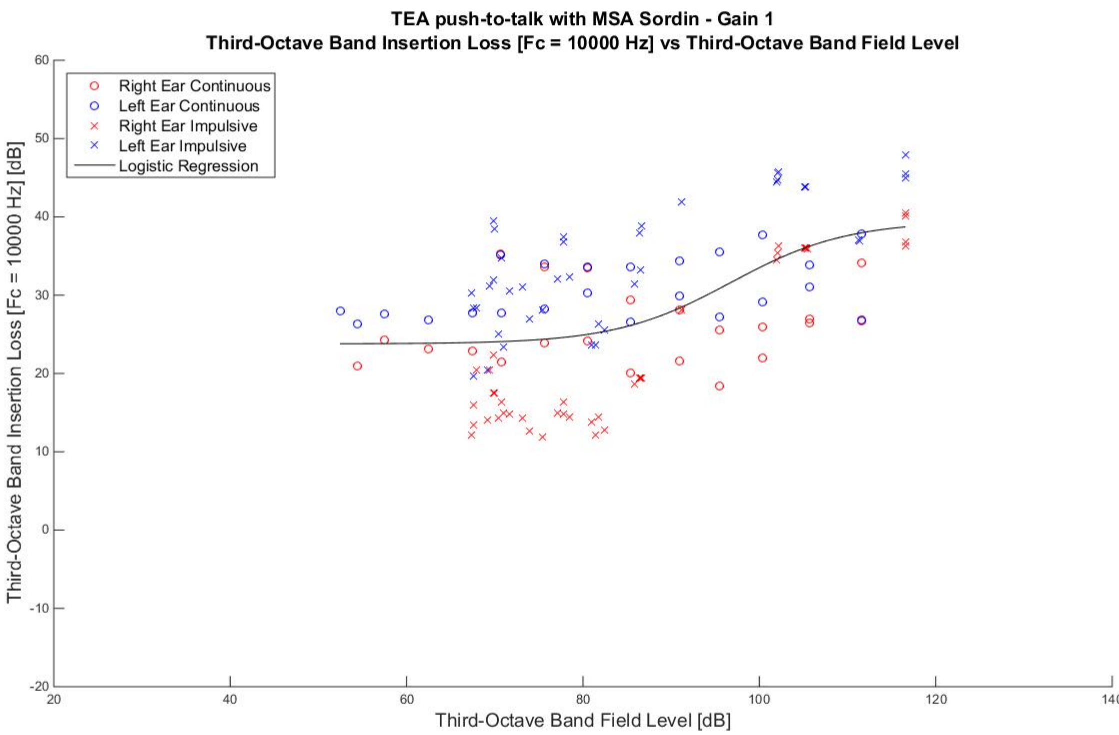

Figure A-369. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 10000 Hz.

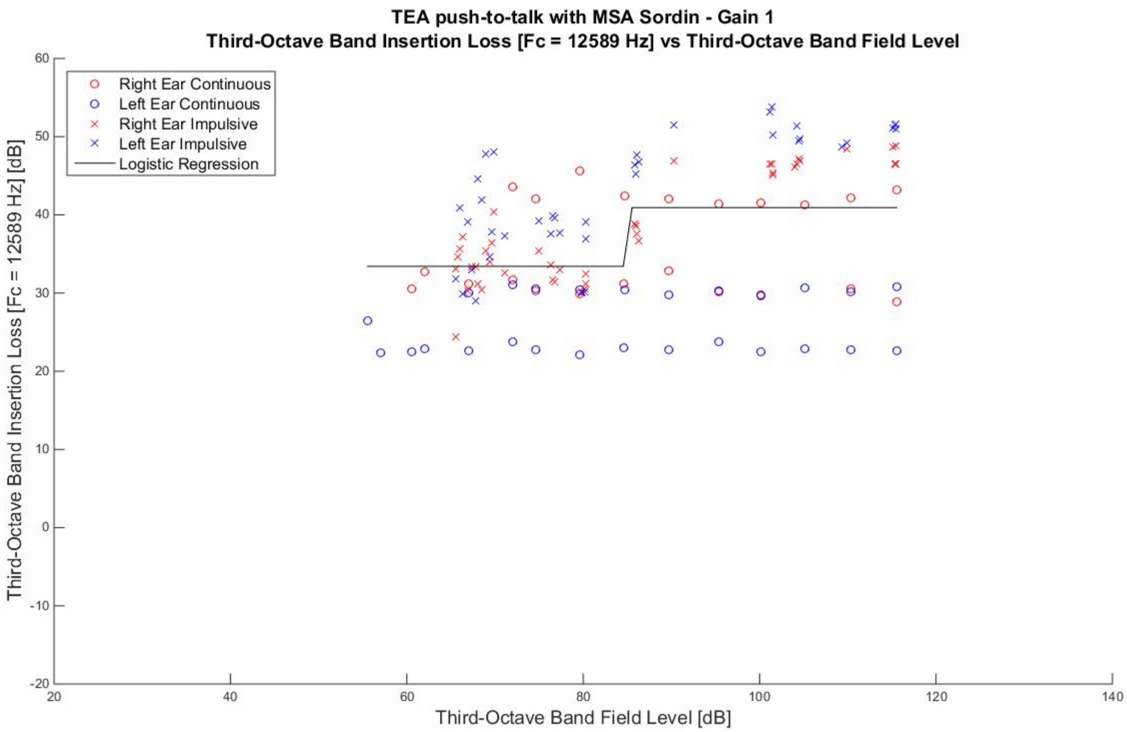

Figure A-370. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 12589 Hz.

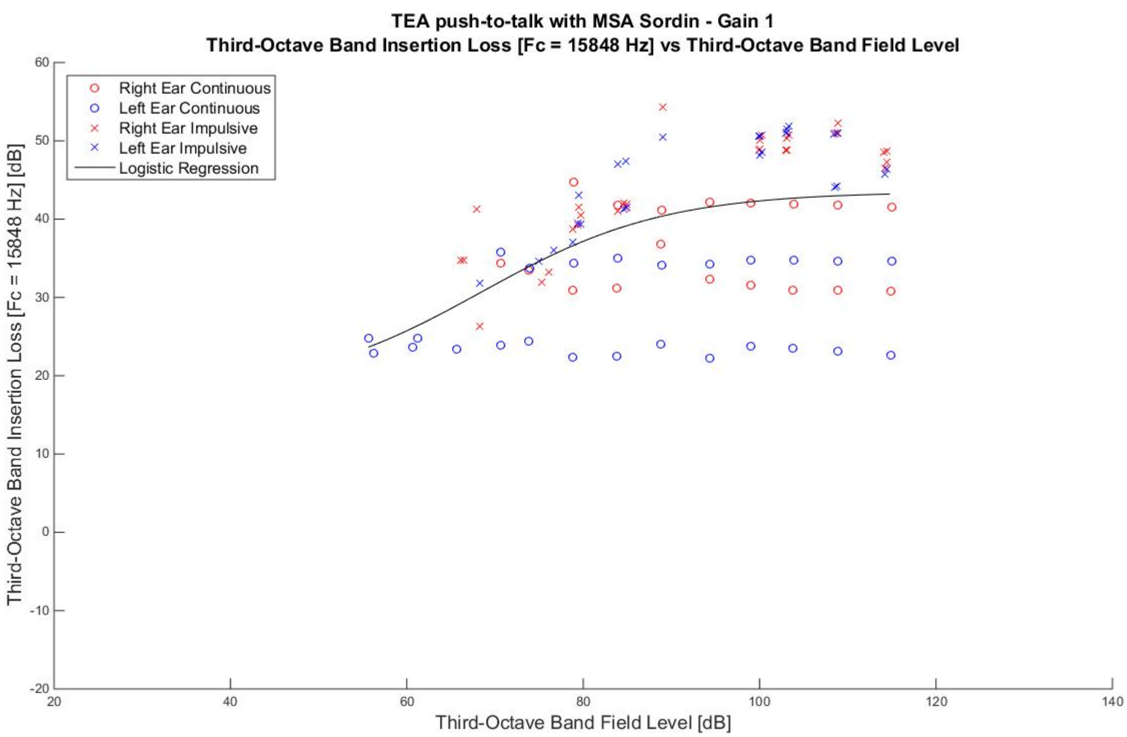

Figure A-371. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 15848 Hz.

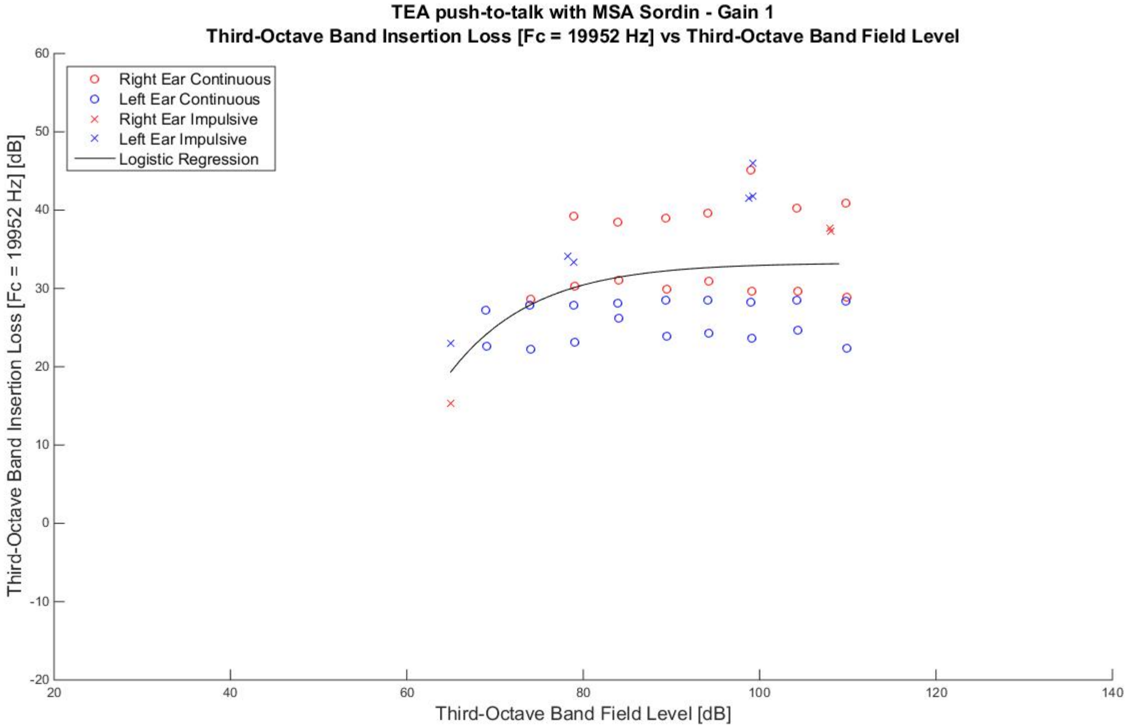

Figure A-372. MSA Sordin - Gain 1 - 1/3rd OB IL vs. 1/3rd OB field level - 19952 Hz.

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